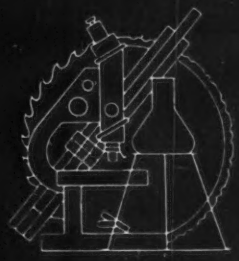
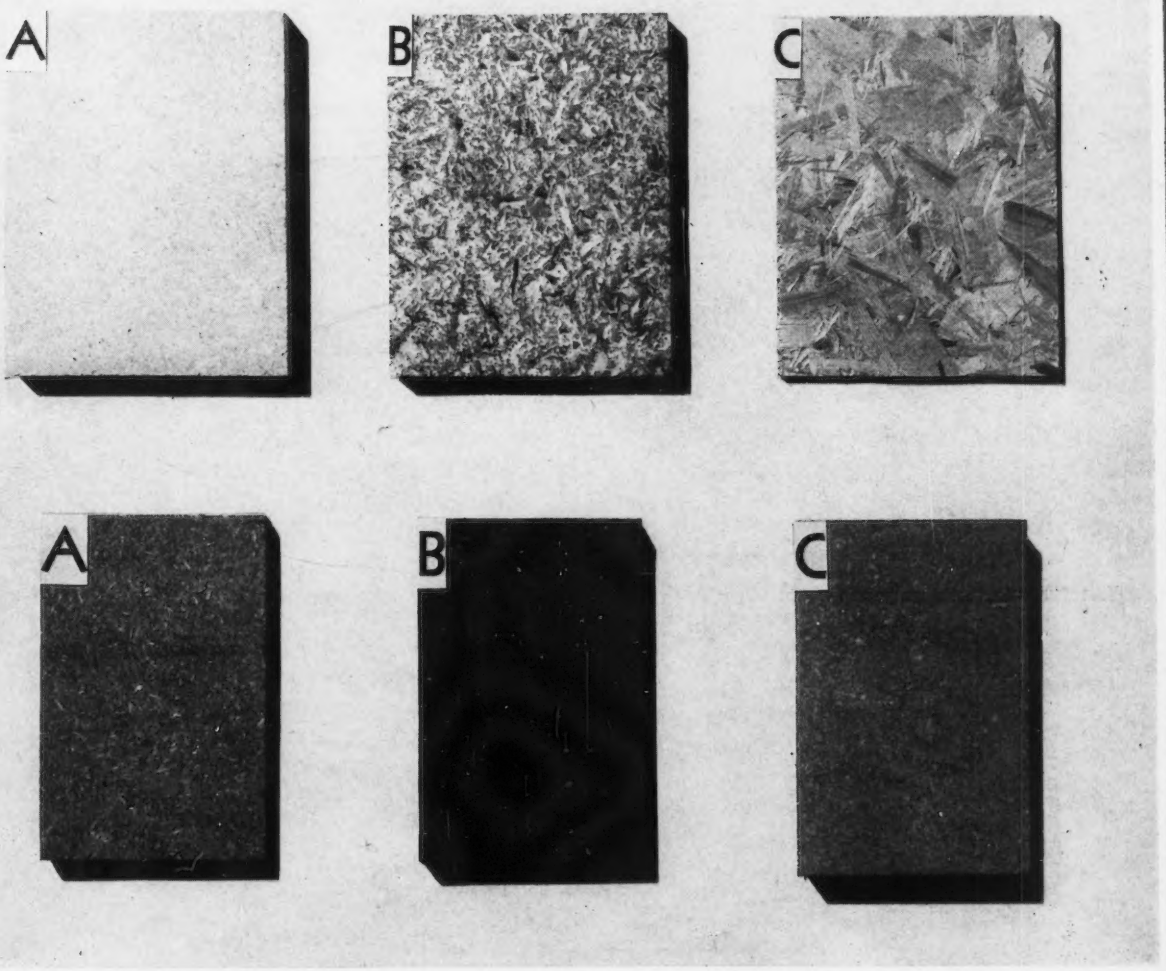
SURFACE EFFECTS ON GLUE-JOINT STRENGTH p. 345

Forest Products Journal



Vol. VII, No. 12 December, 1957



CLASSIFICATION AND COMPOSITION OF PARTICLE BOARDS . . . p. 11-A

The shape of the particle, the number of layers, the process . . . these determine end-use properties.

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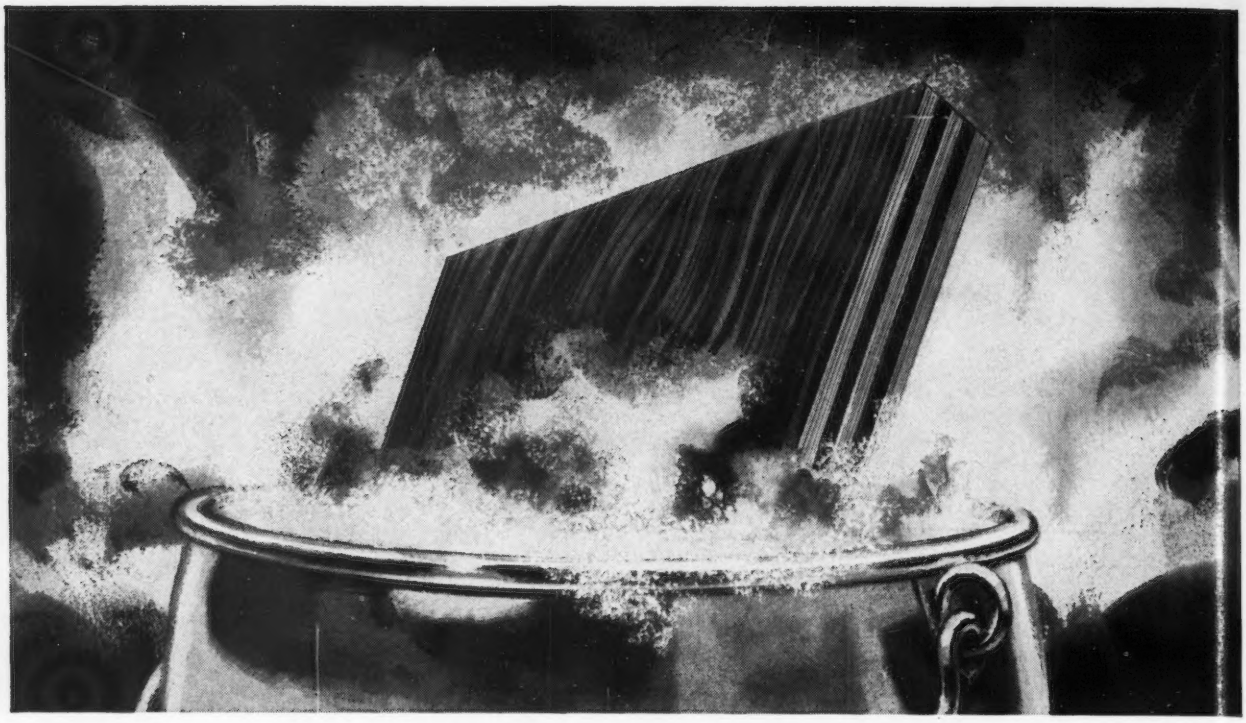

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Those even slightly troubled by waterproof bond specifications CS 35-56, Type I, can take comfort. You can surpass them with two Cyanamid Adhesive Resins!

NEW MELURAC 305 IS BETTER—AND COSTS NO MORE! With persistent upward revisions of adhesive requirements, we are proud to announce MELURAC 305, a considerably improved melamine-urea-formaldehyde adhesive resin, *at no increase in price!*

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THE FOREST PRODUCTS JOURNAL is published monthly by the Forest Products Research Society, P. O. Box 2010, University Station, Madison 5, Wisconsin. Second-class postage paid at Madison, Wisconsin.

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FOREST PRODUCTS JOURNAL

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Feb. 2–3, 1959: Pacific Northwest Section Meeting, Coos Bay, Ore.

May 25–26, 1959: Joint Eastern Canadian—Northeast Spring Section Meeting, Ottawa, Ontario.

June 28–July 3, 1959: Thirteenth National Meeting, San Francisco, Calif.

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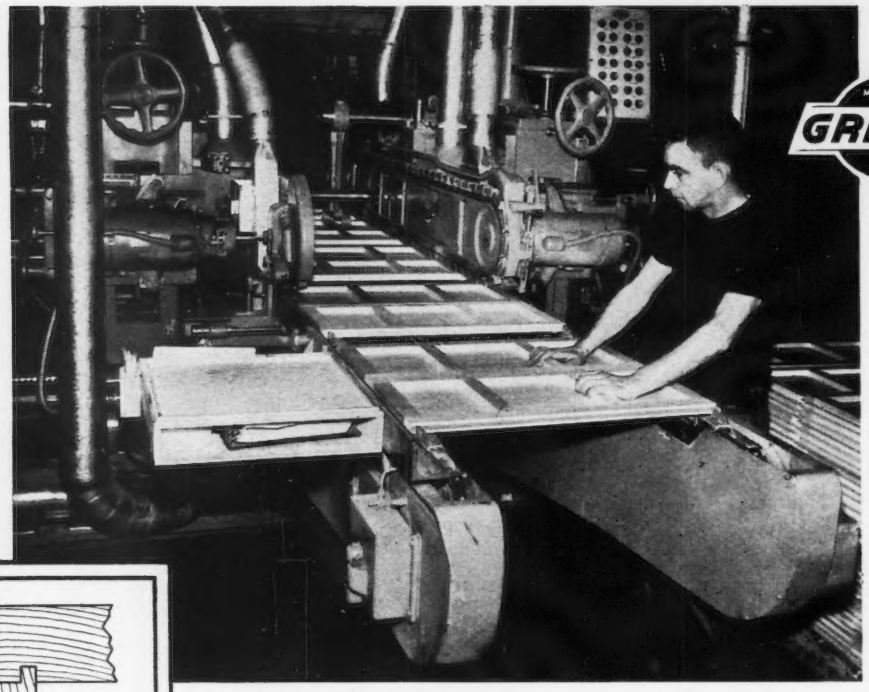

MACHINERY & TOOLS
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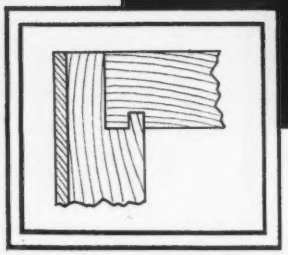
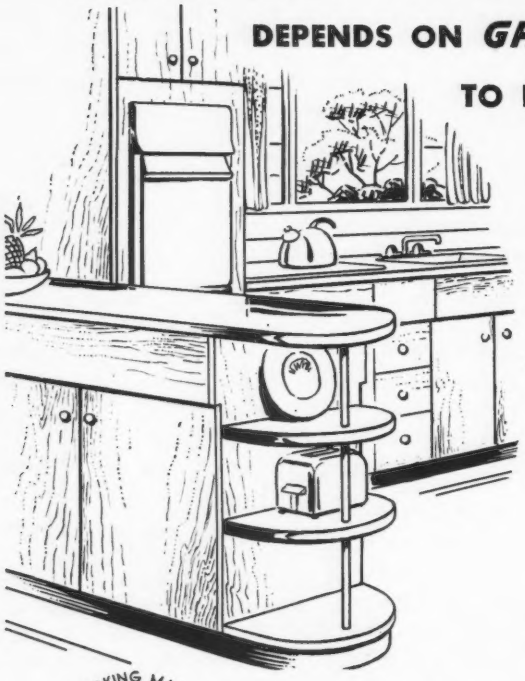


MORGAN

DEPENDS ON *GREENLEE* No. 545 DOUBLE-END TENONER TO PRODUCE ACCURATE LOCK-CORNER JOINTS



Wood cabinets for kitchens manufactured by Morgan Company, Oshkosh, Wisconsin have many exclusive features. One of these is the Morgan self-aligning lock joint which makes assembly easy . . . holds cabinets true and square.

These joints are cut in the cabinet end-panels at the rate of 600 per hour on the Greenlee No. 545 Double-End Tenoner shown above. Necessarily, close tolerances are of utmost importance. On an average run of 20,000 pieces, plant officials say the Greenlee "545" will hold to .008" at all times.

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Constantly exploring and developing new products and methods, "Abrasive Tech" engineers may help you speed production, save you time and money. There are 17 well-equipped "Abrasive Tech" Methods Rooms ready to help solve problems or demonstrate new techniques in: Atlanta, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Detroit, Grand Rapids, High Point, Indianapolis, Los Angeles, Teterboro, Camden, San Francisco, Seattle, St. Louis, and Brantford, Canada. Main office and plant: Troy, N. Y.

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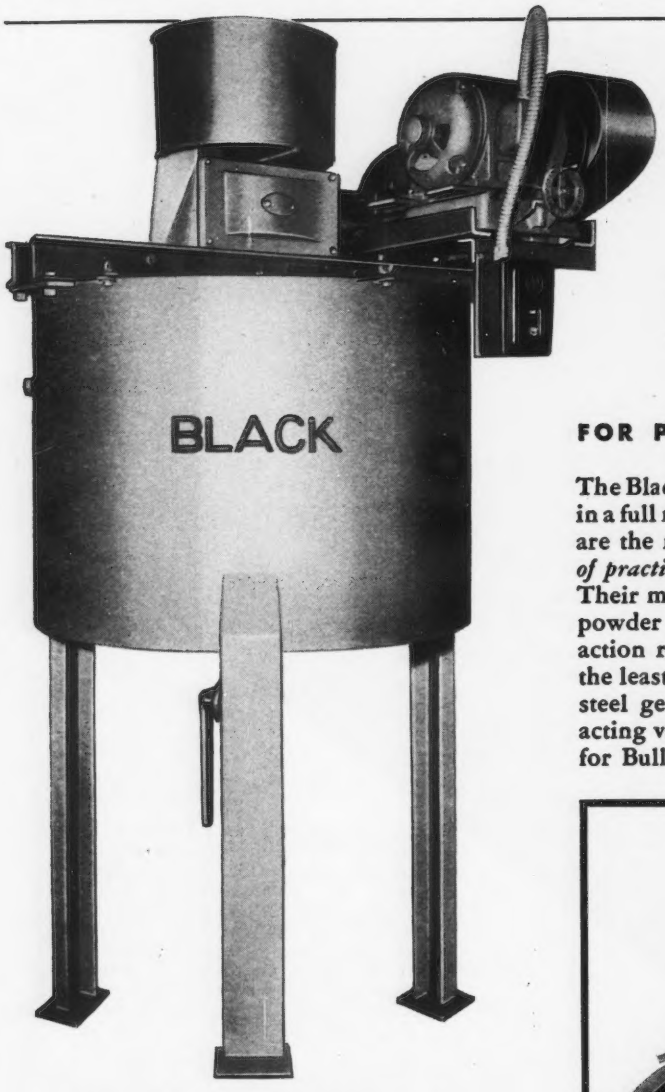
IW-6

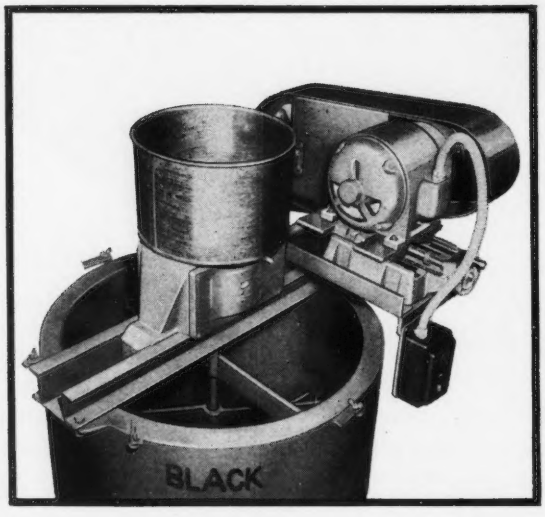
THE BLACK BROTHERS



Cold glue MIXERS

FOR POWDERED OR LIQUID ADHESIVES

The Black Brothers stationary cold glue mixers are made in a full range of capacities from 10 to 500 gallons. They are the result of *expert engineering combined with years of practical experience in glue equipment manufacturing.* Their many special features include: (1) Sifter for glue powder (2) Double agitators which give a beating action resulting in the smoothest possible mixture in the least possible time (3) Pressure lubrication (4) Cut steel gears . . . hardened and lapped (5) Large quick-acting valve at bottom. For full information write today for Bulletin 11-I.

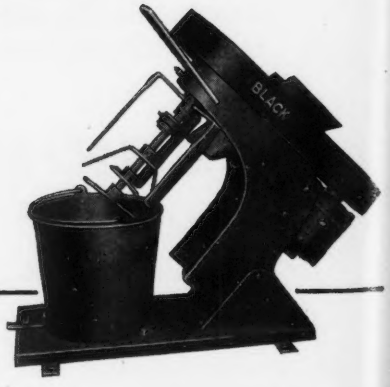


TWO-WAY AGITATION ▶

To the right is a partial view of a 60 gallon cold glue mixer arranged with a variable speed drive and water jacket. The covers have been removed showing accessibility for cleaning, and also the double agitator arrangement. Note the thick double walled tank permitting free circulation of water for cooling the glue batch.

PORTABLE MOTOR DRIVEN GLUE MIXER ▶

The Black Brothers portable motor driven cold glue mixer is made in 2, 5, 7½, and 15 gallon sizes. It has a number of exclusive Black Brothers features such as a glue powder sifter, two-way agitation, and specially shaped flat paddles to give a beating action to the agitator. In addition this convenient, portable mixer has a hinged arm that may be swung up to allow the pail to be inserted or removed. This mixer is also being used extensively in the mixing of catalysts and hardeners. Write for Supplement to Bulletin 11-I.



"If It Is Gluing Equipment — We Have It"

THE BLACK BROTHERS CO., INC.

MENDOTA 8, ILLINOIS

FPRS NEWS-DIGEST

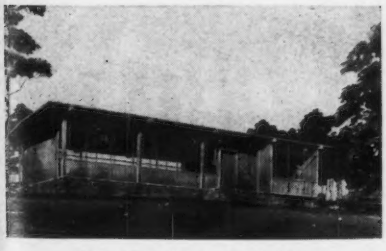
Volume VIII DECEMBER, 1958 Number 12

PRESIDENT'S COLUMN

State of the Society, 1958

W. J. EASON

MEMPHIS, TENN., Dec. 15. — Following our annual custom I would like to give you, our members, a brief report of your Executive Board's stewardship for the current year. Before doing so, however, I would like first to acknowledge the fine efforts of the men who make up your Executive Board, Section, and Division leadership. During our recent two-day meeting in Chicago, all eleven of our regional representatives and officers were present. They met the first evening until well after 10:00 p.m.; and started in again the next day at 9:00, taking time only for lunch. Not completing all the business at hand, they agreed to meet again at our new headquarters in Madison late in January. I believe that their record of attendance and constructive work, for which they are in no way reimbursed, should be recognized and appreciated by all of us.

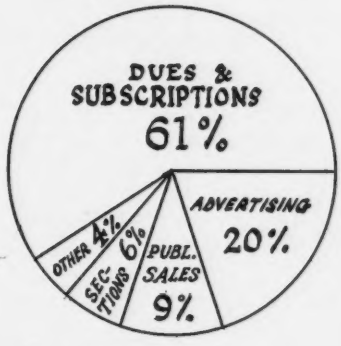


New FPRS Home in Madison

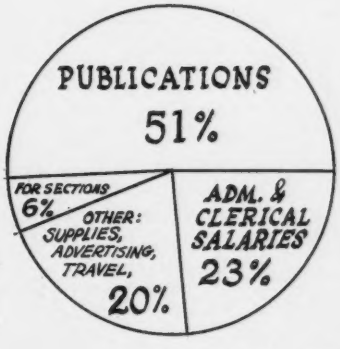
New Executive Office Building

Our greatest single achievement during 1958 was the construction and occupancy of our new Executive Office Building. This was made possible by the material and financial aid of more than 400 individuals and companies represented in our Society. Our staff (as you will see on the following pages) is now happily located in their new home, surrounded by an environment of numerous species of fine woods and wood-base materials, as well as harmonizing office furniture. It now appears that our building will be 100% paid-for with the exception of minor property assessments at the close of business, December 31. Thus, in five years we, the members of FPRS, have acquired a property that is valued at $72,000.

Operating Finances

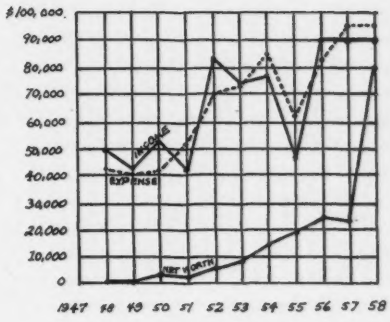


Where the money comes from . . .



. . . and where it goes

The year 1958 was a trying one, financially. While in no measure attempting to minimize our publication or other services to our members, we strove to develop income of about $90,000. It now appears that our expenditures will exceed income by about $2,000. Although we are a non-profit Society, normally we attempt to develop a reasonable cash surplus toward a future need. This will be one of our objectives in 1959. Our inventory of office furniture and equipment, worth $10,000, added to our building raises the net asset equity of each member to about $23. A brief idea of how our income and disbursements are distributed is illustrated in the accompanying charts.



Income vs. expenditure by years

Membership Levels Off

After ten years of appreciable membership increase, 1958 also witnessed a leveling off in FPRS total membership at about 3,700. From what we have been able to observe of the experience of other technical societies, this was somewhat to be expected in view of

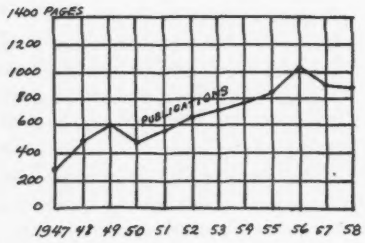
Membership growth by years

the general slowness of the industrial economy. I should add that our efforts to obtain new members continue unabated, and any assistance our members can give us in this task will be sincerely appreciated.

Our Office Staff

Our executive office staff, under the direction of executive secretary Frank J. Rovsek, has grown from a part-time operation in its first year, 1947, to a total of eight persons today, of which two are employed half-days. A description of their varied duties follows, but I do want to pay special tribute to their fine team-work and efforts in our behalf at this time.

Our Publications



Journal pages published each year

Our FOREST PRODUCTS JOURNAL, which serves the several individual segments of our industry as well as the interests of both the scientific, technically-trained, and the non-technical, production members of the Society, has increased in stature and world recognition with each succeeding year. In 1958 we published a total of 1,000 editorial pages.

12th National Meeting

In research and development, as in all fields of endeavor, it is essential that participants be able to meet from time to time to share information, review progress, and plan for the future. This year, our 12th National Meeting, held at Madison, was attended by 650 men and women. Our vote of thanks is certainly due to our outstanding program and arrangements committees for providing us with another technically and financially successful meeting.

Our 14 Sections

All of our 14 Sections were active during the year, and I personally enjoyed visiting seven of their meetings during the latter half of 1958. Our Sections are the "heart" of our Society, pumping the life blood responsible for the continued health and growth of FPRS.

Our 14 Divisions

Our Divisions, together with their numerous sub-committees, serve some 2,000 affiliated members directly and the entire membership indirectly. Their "Annual Reviews", which cover important research and development progress that has taken place during the calendar year, are published annually in our February JOURNAL. Of particular note, during 1958, was the enlargement of the work of our Industry–Education Division to incorporate sub-committees in each of the 14 Sections for the purpose of cooperating with the National Lumber Manufacturers Association and local universities and industries in a program to encourage promising high school students to take up careers in the forest products industry.

What of the Future

It is becoming increasingly apparent that, if we are to carry out fully the objectives our founders envisioned back in 1947, we are going to have to grow both in numbers and finances. Certainly an industry that is comprised of more than 50,000 separate sawmill, lumber, plywood, composition board, woodworking, furniture, pulp, paper and miscellaneous wood products industries, should be able to sustain a technical society many times our present size. I envision the day when FPRS will number 10,000 members, and through resultant economies will be in a position to render even greater publication, personalized, and geographic service to its members than it is presently able to do. While our progress has been an inspiration to behold, we have barely began to scratch the surface.

Again, my appreciation to you for your devoted interest, and my sincere best wishes for the year ahead.

W. JETER EASON, *President*

Members Urged to Pay 1959 Dues

FPRS Members should now be receiving invoices for their 1959 dues. The Executive Office urges all members to send in their remittance for dues payment and choices of Division Affiliation as quickly as possible.

"Southeastern Section" New Florida–Georgia–Alabama Name

The Florida-Georgia-Alabama Section has recently changed its name to "Southeastern Section", it was announced recently. Section members voted the change by mail ballot, and the change was officially approved by the president.

Area Timber Resource Review Discussed at Nov. Meeting of Rocky Mountain Section

The Fall Meeting of the Rocky Mountain Section was held Nov. 13 at the Albany Hotel in Denver, Colo., Lincoln Mueller, Section Secretary reported.

Mr. Troxell was first speaker on the program and discussed the joint FPRS-NLMA program to attract students to the forest products industries. He outlined the curriculum at Colorado State University and the facilities at the forest products laboratory for training students. Earl Priegel, Forest Service, spoke on the results of the Timber Resource Review as they applied to timber resources in the central Rocky Mountain area.

The results of timber harvesting research, including skyline-crane tests, underway at the Rocky Mountain Forest Experiment Station were discussed by Francis Herman. "The Moving Forest", a Russian film, was also shown by Mr. Herman.

Fred Malcolm, USFPL, gave an illustrated talk at the afternoon session, on improving the efficiency and quality of sawmill production. The American Forest Products Industries tree farm program in the Rocky Mountain area was discussed by Alan Miller, regional manager of the association.

During the business meeting, the Section voted to hold a meeting in February, 1959, in conjunction with Foresters' Day Activities at Colorado State University and the opening of the new forest products laboratory. H. E. Troxell, Colorado State University, was asked to arrange the meeting by chairman Robert S. Bader.

NAMES IN THE NEWS

Alfred J. Stamm has been named research associate professor of wood technology in the School of Forestry at North Carolina State College, it was announced recently. Dr. Stamm's appointment will be effective July 1, 1959. A subject matter specialist with the U. S. Forest Products Laboratory, Stamm is co-author of the book "Chemical Processing of Wood", which was published in 1953.

John B. Veach, president, Hardwood Corp. of America, was re-elected president of American Forest Products Industries, Inc., at the association's annual meeting in Washington, D. C., Nov. 7.

Elected to the new post of Assistant Secretary-Treasurer for the California Redwood Assoc. is **Willard T. Pratt.**

Four persons have been appointed to three-year terms on the Technical Advisory Council of the University of California's Forest Products Laboratory. They are: **Lester J. Carr,** president, L. J. Carr Co., Sacramento; **Ralph Hodges, Jr.,** forester, Big Bear Timber Co., Sacramento; **Bryne Manson,** product development engineer, Simpson Redwood Co., Arcata; and **Alfred Smith,** general manager, Union Planing Mill, Stockton.

NLMA Chooses New Officers

NEW OFFICERS elected at the NLMA annual meeting, Nov. 10–13, in Washington, D. C., are (l. to r.) Thomas J. McHugh, Atlantic Lbr. Co., first vice president; Robert M. Ingram, E. C. Miller Cedar Lbr. Co., president; and N. Floyd McGowin, W. T. Smith Lbr. Co., board chairman.

Operating Policies Drawn up at Recent Nov. NLMA Meeting

A new statement of operating policies and procedures highlighted the 1958 annual meeting of NLMA directors and committees, Nov. 10–13, at Washington, D. C. The policy statement outlines the association's position on major national issues.

Central theme of the policy statement reaffirms NLMA's support of "the principles and fundamentals of competitive private enterprise, individual initiative and responsibility, and just rewards for productive efforts".

Attracting major interest at the meeting were plans for the first year's operation of the new National Wood Promotion Program. The Promotion committee, under the chairmanship of A. B. Hood, authorized establishment of a National Wood Council to coordinate the promotional programs of all wood-industry organizations. A wood [illegible]

can be made on the control panel without touching the carriage.

Through the use of a master potentiometer, it is possible in one adjustment to alter all settings to exactly the same degree in correcting accuracy following saw changes or adjustment of the carriage knees. An optional control is the push-button sawyer station. More information is available from the Mill Equipment Inc., 5219 First Ave. South, Seattle 8, Wash.

See page 34–A for more New Products Listing

EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Positions Offered

E–324—Project engineer needed to perform product design work of substantial importance. Will work under supervision of Product Development Mgr. but will have considerable latitude for independent action and decision. Will occasionally supervise one or more persons in detailing, model-making, and testing. (Dec.)

E–325—Assistant Manager wanted for department dealing with product planning and development in large southern lumber operation. Forestry background desirable with major in wood utilization or industrial engineering. Master's degree preferred (Dec.)

E–327—Experienced sales manager needed for Pacific Coast sawmill machinery manufacturing firm. Must have proven sales

hesives. For the last 4 years has worked as wood preservation specialist on bamboos at India Forest Products Laboratory. Familiar with electron microscopy. Received M.S. degree with honors. Educated in India. Age, 28. Will pay own expenses to come to U. S. (Dec.)

No. 495—Position desired in research or product development with firm producing laminated structures, plywood, or similar products. Holds B.S. in applied sciences and will complete work on M.S. in wood utilization in January 1959. Has research experience in lamination. Prefers South or Southeast location. (Dec.)

No. 496—Production engineer with M.S. in wood technology wants to relocate. Has seven years industrial experience in production supervision, planning and scheduling in furniture manufacturing, plant layout and construction, machine set-up, industrial painting and hydraulics. (Dec.)

No. 497—Product development, sales, or promotion position desired by wood technologist. Experienced in logging, hardboard, production and sales. Holds B.S. and M.S. in forest products and has completed requirements for Ph.D. Currently in production supervision and setting up national distribution outlets. Age, 31. (Dec.)

No. 498—Graduate forester desires position in sales promotion or editorial work. Experienced in forestry, technical writing in wood preservation. Has published in trade magazines, produced company literature, and trade association proceedings. Experienced in selling, warehousing, traffic and purchasing. (Dec.)

No. 499—Position desired in large mill making diversified wood products. Has unusual mechanical ability. Holds B.S. in wood utilization. Experienced in the development of new products, new treating solutions, and plant production. In 1954 was a recipient of an NLMA–TECO summer scholarship. (Dec.)

No. 500—Position in research, technical service, or promotion desired by wood technologist. Has eight years experience in the management of research programs, with emphasis on preservation. Experienced in operation of a commercial treating plant (Dec.)

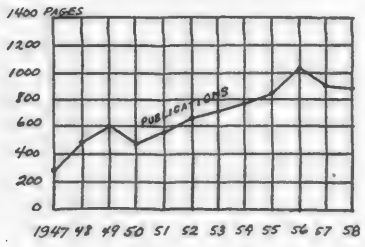
No. 501—Position in quality control

the general slowness of the industrial economy. I should add that our efforts to obtain new members continue unabated, and any assistance our members can give us in this task will be sincerely appreciated.

Our Office Staff

Our executive office staff, under the direction of executive secretary Frank J. Rovsek, has grown from a part-time operation in its first year, 1947, to a total of eight persons today, of which two are employed half-days. A description of their varied duties follows, but I do want to pay special tribute to their fine team-work and efforts in our behalf at this time.

Our Publications



Journal pages published each year

Our FOREST PRODUCTS JOURNAL, which serves the several individual segments of our industry as well as the interests of both the scientific, technically-trained, and the non-technical, production members of the Society, has increased in stature and world recognition with each succeeding year. In 1958 we published a total of 1,000 editorial pages.

12th National Meeting

In research and development, as in all fields of endeavor, it is essential that participants be able to meet from time to time to share information, review progress, and plan for the future. This year, our 12th National Meeting, held at Madison, was attended by 650 men and women. Our vote of thanks is certainly due to our outstanding program and arrangements committees for providing us with another technically and financially successful meeting.

Our 14 Sections

All of our 14 Sections were active during the year, and I personally enjoyed visiting seven of their meetings during the latter half of 1958. Our Sections are the "heart" of our Society, pumping the life blood responsible for the continued health and growth of FPRS.

Our 14 Divisions

Our Divisions, together with their numerous sub-committees, serve some 2,000 affiliated members directly and the entire membership indirectly. Their "Annual Reviews", which cover important research and development progress that has taken place during the calendar year, are published annually in our February JOURNAL. Of particular note, during 1958, was the enlargement of the work of our Industry–Education Division to incorporate sub-committees in each of the 14 Sections for the purpose of cooperating with the National Lumber Manufacturers Association and local universities and industries in a program to encourage promising high school students to take up careers in the forest products industry.

What of the Future

It is becoming increasingly apparent that, if we are to carry out fully the objectives our founders envisioned back in 1947, we are going to have to grow both in numbers and finances. Certainly an industry that is comprised of more than 50,000 separate sawmill, lumber, plywood, composition board, woodworking, furniture, pulp, paper and miscellaneous wood products industries, should be able to sustain a technical society many times our present size. I envision the day when FPRS will number 10,000 members, and through resultant economies will be in a position to render even greater publication, personalized, and geographic service to its members than it is presently able to do. While our progress has been an inspiration to behold, we have barely began to scratch the surface.

Again, my appreciation to you for your devoted interest, and my sincere best wishes for the year ahead.

W. JETER EASON, *President*

Members Urged to Pay 1959 Dues

FPRS Members should now be receiving invoices for their 1959 dues. The Executive Office urges all members to send in their remittance for dues payment and choices of Division Affiliation as quickly as possible.

"Southeastern Section" New Florida–Georgia–Alabama Name

The Florida-Georgia-Alabama Section has recently changed its name to "Southeastern Section", it was announced recently. Section members voted the change by mail ballot, and the change was officially approved by the president.

Area Timber Resource Review Discussed at Nov. Meeting of Rocky Mountain Section

The Fall Meeting of the Rocky Mountain Section was held Nov. 13 at the Albany Hotel in Denver, Colo., Lincoln Mueller, Section Secretary reported.

Mr. Troxell was first speaker on the program and discussed the joint FPRS-NLMA program to attract students to the forest products industries. He outlined the curriculum at Colorado State University and the facilities at the forest products laboratory for training students. Earl Priegel, Forest Service, spoke on the results of the Timber Resource Review as they applied to timber resources in the central Rocky Mountain area.

The results of timber harvesting research, including skyline-crane tests, underway at the Rocky Mountain Forest Experiment Station were discussed by Francis Herman. "The Moving Forest", a Russian film, was also shown by Mr. Herman.

Fred Malcolm, USFPL, gave an illustrated talk at the afternoon session, on improving the efficiency and quality of sawmill production. The American Forest Products Industries tree farm program in the Rocky Mountain area was discussed by Alan Miller, regional manager of the association.

During the business meeting, the Section voted to hold a meeting in February, 1959, in conjunction with Foresters' Day Activities at Colorado State University and the opening of the new forest products laboratory. H. E. Troxell, Colorado State University, was asked to arrange the meeting by chairman Robert S. Bader.

NAMES IN THE NEWS

Alfred J. Stamm has been named research associate professor of wood technology in the School of Forestry at North Carolina State College, it was announced recently. Dr. Stamm's appointment will be effective July 1, 1959. A subject matter specialist with the U. S. Forest Products Laboratory, Stamm is co-author of the book "Chemical Processing of Wood", which was published in 1953.

John B. Veach, president, Hardwood Corp. of America, was re-elected president of American Forest Products Industries, Inc., at the association's annual meeting in Washington, D. C., Nov. 7.

Elected to the new post of Assistant Secretary-Treasurer for the California Redwood Assoc. is **Willard T. Pratt.**

Four persons have been appointed to three-year terms on the Technical Advisory Council of the University of California's Forest Products Laboratory. They are: **Lester J. Carr,** president, L. J. Carr Co., Sacramento; **Ralph Hodges, Jr.,** forester, Big Bear Timber Co., Sacramento **Bryne Manson,** product development engineer, Simpson Redwood Co., Arcata and **Alfred Smith,** general manager Union Planing Mill, Stockton.

"Happy New Year" from the Staff in Our New Building

The New Year finds the FPRS staff well established in our New Executive Office Building. Expanded facilities have made Society operations more efficient. Little did FPRS members realize that in a relatively short time, the Society would have its own modern building. When in Madison visit your FPRS office. We'll be glad to see you!

"Hello there", is the way Mrs. Janette Arneson will greet you when you visit the Society's office. Here, as receptionist, she greets John McMillen, Chairman of the Wood Drying Division.

Meet Executive Secretary Frank J. Rovsek. As administrative officer of our more than 3700-member FPRS, he is concerned with maintaining the health of the Society and its continued growth.

A keen knowledge of Society details is an exceptional quality of the job performed by Mrs. Louise Dalton, Secretary to Mr. Rovsek. She supervises clerical operations and is the FPRS bookkeeper.

Maintenance of up-to-date membership records is the principal work of Mrs. Arneson. Fastidious detail is involved in her daily entering of new members, listing of address changes and invoicing.

FPRS newest staff member, Mrs. Claire Joyner works principally on new membership activities of the Society. Here, she is preparing a group of letters designed to attract new members to FPRS.

The Society's central filing system is here being used by Mrs. Florence Van Kleeck. With FPRS for eight years, she now works half-days and helps out with whatever is urgent at the moment.

The mailing room is located on the lower level. Mrs. Van Kleeck is running a membership prospect list on the addressing machine, while Mrs. Dalton makes a photo copy of one of the many queries received and answered each week.

Here's Robert H. Hamre, editor of the Forest Products Journal. Bob selects and edits the articles for each issue and takes care of the production phase. He also directs the reviewing of papers.

Writing and production of the FPRS news section for the Journal is one of the main tasks of Mrs. Sandra Parrini. Other jobs include issuing news releases before and after National Meetings.

Publications sales and advertising records are handled by Arthur Heim, who works half-days. Dedication to detail characterizes his work in filling reprint orders and his dealings with advertisers.

NLMA Chooses New Officers

NEW OFFICERS elected at the NLMA annual meeting, Nov. 10–13, in Washington, D. C., are (l. to r.) Thomas J. McHugh, Atlantic Lbr. Co., first vice president; Robert M. Ingram, E. C. Miller Cedar Lbr. Co., president; and N. Floyd McGowin, W. T. Smith Lbr. Co., board chairman.

Operating Policies Drawn up at Recent Nov. NLMA Meeting

A new statement of operating policies and procedures highlighted the 1958 annual meeting of NLMA directors and committees, Nov. 10–13, at Washington, D. C. The policy statement outlines the association's position on major national issues.

Central theme of the policy statement reaffirms NLMA's support of "the principles and fundamentals of competitive private enterprise, individual initiative and responsibility, and just rewards for productive efforts".

Attracting major interest at the meeting were plans for the first year's operation of the new National Wood Promotion Program. The Promotion committee, under the chairmanship of A. B. Hood, authorized establishment of a National Wood Council to coordinate the promotional programs of all wood-industry organizations. A wood mark and slogan were adopted by the committee to help merchandise the promotional effort.

In other action, the American Wood Preservers Institute was voted the 17th association member of NLMA. The appointment of a special subcommittee was authorized to study the question of other lumber and allied organizations interested in NLMA membership.

NEW PRODUCTS—LITERATURE

Selectric Electronic Controls

A system of electronic control for the Selectric sawyer-operated setworks system has recently been developed by Mill Equipment, Inc. Featured is a brain unit that mounts on the carriage and transforms finger-tip commands of the sawyer into carriage performance.

A control center for the sawbox makes possible infinite variation in the length of sets. Adjustment of settings can be made on the control panel without touching the carriage.

Through the use of a master potentiometer, it is possible in one adjustment to alter all settings to exactly the same degree in correcting accuracy following saw changes or adjustment of the carriage knees. An optional control is the push-button sawyer station. More information is available from the Mill Equipment Inc., 5219 First Ave. South, Seattle 8, Wash.

See page 34–A for more New Products Listing

EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Positions Offered

E–324—Project engineer needed to perform product design work of substantial importance. Will work under supervision of Product Development Mgr. but will have considerable latitude for independent action and decision. Will occasionally supervise one or more persons in detailing, model-making, and testing. (Dec.)

E–325—Assistant Manager wanted for department dealing with product planning and development in large southern lumber operation. Forestry background desirable with major in wood utilization or industrial engineering. Master's degree preferred. (Dec.)

E–327—Experienced sales manager needed for Pacific Coast sawmill machinery manufacturing firm. Must have proven sales ability and should be familiar with sawmills and lumber industry. (Dec.)

Employment Wanted

No. 493—June 1958 graduate of New York State College of Forestry with B.S. in wood utilization is interested in employment in the wood preservation field. Experienced in operating a small pressure-treating cylinder. (Dec.)

No. 494—Position desired by chemist. Has research experience in plywood adhesives. For the last 4 years has worked as wood preservation specialist on bamboos at India Forest Products Laboratory. Familiar with electron microscopy. Received M.S. degree with honors. Educated in India. Age, 28. Will pay own expenses to come to U. S. (Dec.)

No. 495—Position desired in research or product development with firm producing laminated structures, plywood, or similar products. Holds B.S. in applied sciences and will complete work on M.S. in wood utilization in January 1959. Has research experience in lamination. Prefers South or Southeast location. (Dec.)

No. 496—Production engineer with M.S. in wood technology wants to relocate. Has seven years industrial experience in production supervision, planning and scheduling in furniture manufacturing, plant layout and construction, machine set-up, industrial painting and hydraulics. (Dec.)

No. 497—Product development, sales, or promotion position desired by wood technologist. Experienced in logging, hardboard, production and sales. Holds B.S. and M.S. in forest products and has completed requirements for Ph.D. Currently in production supervision and setting up national distribution outlets. Age, 31. (Dec.)

No. 498—Graduate forester desires position in sales promotion or editorial work. Experienced in forestry, technical writing in wood preservation. Has published in trade magazines, produced company literature, and trade association proceedings. Experienced in selling, warehousing, traffic and purchasing. (Dec.)

No. 499—Position desired in large mill making diversified wood products. Has unusual mechanical ability. Holds B.S. in wood utilization. Experienced in the development of new products, new treating solutions, and plant production. In 1954 was a recipient of an NLMA–TECO summer scholarship. (Dec.)

No. 500—Position in research, technical service, or promotion desired by wood technologist. Has eight years experience in the management of research programs, with emphasis on preservation. Experienced in operation of a commercial treating plant. (Dec.)

No. 501—Position in quality control, production management or practical research desired. Holds B.S. in wood utilization. Experienced in wood finishing. (Dec.)

PRODUCTION SUPERINTENDENT FOR HARDBOARD

West Coast integrated operation needs qualified supervisor assistant to plant superintendent to take charge of production in the hardboard operation. Replies, kept confidential, should state age, experience, and qualifications.

Send replies to:
E-326 Employment Service
FOREST PRODUCTS RESEARCH SOCIETY
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1959 FOREST PRODUCTS RESEARCH SOCIETY 1959

ADDRESS OF THE EXECUTIVE SECRETARY

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(DATE)

TO THE EXECUTIVE BOARD:

I hereby make application for

- ☐ Supporting Membership ($100)
- ☐ Voting Membership ($15)
- ☐ Associate Membership ($15)

} in the Forest Products Research Society, including regular publications of the Society. CHECK ONE (Qualifications defined on reverse of this sheet)

Note: Of $15 or $100 membership, $11.25 is paid for a one year subscription to the FOREST PRODUCTS JOURNAL.

(SIGNATURE)

Please provide *all* of the following information. The Executive Board cannot act on incomplete applications.

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Wood Technology Series

- ☐ No. 20 Particle Board, 1954–56
- ☐ No. 21 Hardboard, 1954–56
- ☐ No. 22 Wood Waste Utilization

FPRS FOREST PRODUCTS JOURNAL
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PARTICLE BOARDS . . .

THEIR CLASSIFICATION AND COMPOSITION[1]

G. G. MARRA
Head, Wood Technology Section, Division of Industrial Research, Washington State College, Pullman

Contrary to earlier opinion, nature of the raw material may be a deciding factor in determining the board to be produced at a given location. There is no "best board" or "best process". Boards are classed as to type of wood (flakes or particles) and number of distinct layers.

Fig. 1.—Board-forming machine at Pack River Lumber Co. Tubes from a circular distributing head facilitate accurate positioning of wafers in the mat.

THE VERSATILITY OF PARTICLE BOARD—in its raw material requirements, in its methods of manufacture, and in its uses—is at once responsible for its rapid rise in the world and for the confusion with which it is often surrounded. Nursed along by German technologists following World War II, it developed lustily in response to the complex economic circumstances prevailing in Germany since that time. With Swiss scientists adding significantly to the art, its onward rush culminated in world recognition at the recent Geneva Conference.[2] The United States, with its envied market potential and enormous raw material supplies, produced its first commercial boards in 1947 and now stands poised for massive exploitation of this relatively new item of commerce. Virtually no wood-using industry today is free from the inviting possibilities of fresh profits from particle board.

This paper will attempt to organize the perplexities of the particle board field, induced, as it were, by its own popularity and universal adaptability. By classifying and sub-dividing the mass of information under study, it is hoped that some perspective may be interjected into the impending development. It is hoped futrher that this description of products, and to some extent processes, will tend to dispel the over-simplified quest for "the best board" or "the best process". It will be seen that the products and their uses are of such diversity that it is not possible to hit all markets with a single, universal board.

Contrary to previous conceptions regarding this industry, the nature of the raw material is now emerging as one of the major dictators of the type of board that may be produced at a given location. A number of other factors, some economic, some technical, also have an important bearing on the question.

Classification of Particle Boards

The gross aspect of the situation may be grasped by reference to the chart in Fig. 2. It should be noted that a major breakdown occurs on the basis of the number of distinct layers of which the board is composed. The number of layers and their composition are immediately reflected process-wise in plant equipment requirements, in board properties, and in production costs. One-layer, two-layer, and three-layer boards appear at the present time to encompass fully the range of possibilities in regard to deliberate stratification of the material in a board. It seems unlikely that more than three layers would prove economical or beneficial, although research in processing techniques could well lead to other means of achieving the same ends.

The second major sub-division of the subject is on the basis of type of wood element used. These may be of two types, either flakes or particles. Unfortunately, the term "particles" now seems to be serving a dual role in the English vocabulary, and is covering composition boards in general. It is used to refer to a variety of elements of indistinct geometry, and also has, by default, come to be used as a generic term for all boards not otherwise classified as fiberboards. Thus the stage is set for a degree of confusion at the outset, and not much hope for relief can be offered even by the Ge-

[1] Presented at the inaugural meeting of the Rocky Mountain Section, FPRS, held Nov. 8, 1957, in Denver, Colo.

[2] First International Consultation on fiberboard and particle board sponsored by FAO and ECE in Geneva, Switzerland, Jan. 21--Feb. 4, 1957.

The Author: George Marra holds BS and MS degrees from New York State College of Forestry at Syracuse and a DF from Duke University. He was an associate professor at West Virginia U. before joining Washington State.

TYPE OF WOOD ELEMENT	BOARD GROUPS		
	ONE-LAYER	TWO-LAYER	THREE-LAYER
PARTICLES Produced by disc grinders or hammermills from chips or shavings (includes fibrous fines)	1. Flat-pressed particles 2. Extruded particles	1. Coarse particle base with fine particle surface	1. Fibrous particle center with fibrous fine surfaces 2. Coarse particle center with fine particle surfaces
	3. Flat-pressed mixture of particles and disintegrated flakes 4. Extruded mixture of particles and disintegrated flakes	2. Particle base with decorative flake overlay 3. Disintegrated flake base with fine particle overlay	3. Disintegrated flake center with fine particle surfaces 4. Coarse particle center with disintegrated flake surfaces 5. Coarse particle center with intact thin flake surfaces
FLAKES Produced by special cutters with knives and wood grain oriented similar to veneer cutting	5. Flat-pressed, intact flakes 6. Flat-pressed, disintegrated flakes 7. Extruded, disintegrated flakes	4. Disintegrated flake base with decorative flake overlay	6. Disintegrated flake center with intact thin flake surfaces 7. Disintegrated flakes: Thick flake center with thin flake surfaces 8. Intact flakes: Thick flake center with thin flake surfaces

Fig. 2.—Classification of wood particleboards on the basis of current and proposed practice in Europe and the United States.

neva Conference. As used for the purpose of this classification, the term "particle" refers to elements developed by hammermill action on chips or planer shavings. The resulting particles in turn are sometimes called "chips" or "splinters", both of which fall short as desirable terms. Attrition-type mills also are occasionally employed for further reduction in particle size.

Flakes, on the other hand, are elements produced by special cutter action on solid wood. The elements are characterized by appreciable length compared to thickness, by uniformity of thickness, and by freedom from cross grain. These flake-type elements are referred to as "engineered particles" in the German literature and as "cut particles" in French. The German term suggests the fact that flakes are produced to predetermined standards in regard to dimensions, as contrasted to the more variable shapes produced by hammermill action. In order to improve handling characteristics of flakes, some type of mild milling may also be performed, which breaks the flakes along natural cleavage planes. In general, flakes result in boards that have higher bending strength with lower resin content than would be the case with particles at comparable densities. This advantage, however, is partially offset by the fact that flakes delivered to a common point in a production system have a higher accumulated cost than any of the particle-type elements.

These two factors, number of layers and type of element, taken in combination, generate nine categories of boards as seen in Fig. 2. Three of these categories involve boards composed entirely of flake-type elements, three involve boards composed of particle-type elements, and an intermediate three are composed of both types of elements. These nine categories include a number of distinct products based upon such factors as: extruded or flat-pressed, thick or thin flakes, disintegrated or intact flakes, and coarse or fine particles. A total of 19 combinations of these factors make up the broad state of the art as presently known. Most of these basic board types have commercial application or are proposed for production. It is possible that others may be added to the list from time to time.

A brief description of the board types listed in Fig. 2 follows:

One-Layer Boards

One-layer boards are subdivided into two distinct groups, flat-pressed boards, and extruded boards, a subdivision that occurs only in the one-layer class of boards. All multi-layer boards are, perforce, flat-pressed.[3]

Flat-pressed refers to the method of pressing the preformed mat, and is simply the conventional plywood-type operation in which a multiplaten hot press is used to consolidate the mass. Extrusion processes, on the other hand, perform the forming and pressing operations simultaneously. A ribbon of board of fixed width, usually four feet, emerges from the extruder and panels of desired length are cut by means of a traveling saw.

The relative merits of the two processes have been the subject of many debates. These debates have delved into process versatility, plant costs, plant output, production costs, and properties of the products. Resolution of these arguments is beyond the scope of this paper, but the final residue may be summed up as follows. If identical mixtures of particles, resins, and wax were converted into boards of equal density by both processes, the products would differ in two important respects. The flat-pressed boards would have high dimensional stability in the plane dimensions and low stability in the thickness direction; the extruded boards would have high stability in the thickness direction and low stablity in *one* of the plane dimensions, that is, in the direction of extrusion. Another point of difference is that flat-pressed boards are essentially uniform in strength in longitudinal and transverse directions, while extruded boards are considerably weaker in the longitudinal direction than in the transverse direction.

These particular differences are reduced when the boards are veneered, as in a crossbanding operation, and the two types then find similar applications in the furniture industry. For this reason, it seems best to classify these products together rather than to use the two processes as a major subdivision of the entire particle board field.

It may be noted that the crossbanding has a triple purpose in the case of extruded boards. It serves as a dimensional stabilizer for the core, as a strength equalizer for the core, and as a cushion to prevent telegraphing of particles into the face. For flat-pressed boards, the crossbanding serves primarily as a cushion and is frequently eliminated when telegraphing tendencies have been reduced by layering or other practices.

1. Flat-Pressed Particles: The flat-pressed method may be regarded as the forerunner of the particle board industry, both in Europe and in the United States. A wide variety of products are possible, depending upon the original starting material, the degree of fineness to which it is ground, resin content, and density of the finished board.

The former Plaswood Company of Wilton, New Hampshire, one of the earliest manufacturers of particle board in the United States, produced a board of this type. They used a particle frequently referred to as a "splinter". Another early manufacturer, Rock Island Millwork Co., Rock Island, Ill., produces a board in this same category under the trade name of "Resinwood". In this case, dry planer shavings form the raw material; they are given an un-

[3] The Bartrev press developed by the Vere Engineering Company, Ltd., of London, England, is a process of board manufacture distinctly different from either the extrusion or the flat-press process. The products, however, should be considered similar to those of the flat-press process.

usually fine grind in a disc mill, after which they are pressed to a high-density board. The final product resembles fiber hardboard in some of its properties, and is sometimes referred to as a "hardboard type" particle board. It finds wide use in school furniture and work benches, both with and without plastic overlays. Although even today it stands out as a "different" type of board, it must still find its place as a typical flat-pressed board in this classification.

The Curtis Co. of Clinton, Iowa, is also among the early pioneers in this field. They developed the "Prespine" product for doors and other millwork items.

Flat-pressed particle board is presently the leading type from the standpoint of volume of production in the United States. It is usually lower in cost than the comparable homogeneous flakeboards, and usually displays higher internal bond strength and higher edge screw-holding ability.

The list of producers or potential producers of flat-pressed particle boards is growing steadily and is now estimated at about 20 plants. Typical among these are Wynnwood Products, Jacksonville, Texas; Graniteboard, Inc., Goffstown, N. H.; Wabash Screen Door, Minneapolis, Minn.; Cavalier Corp., Chattanooga, Tenn.; Weyerhaeuser Timber Co., North Bend, Ore.; and Pacific Plywood Co., Dillard, Ore.

2. Extruded Particles: The history of this method of manufacture parallels that of flat-pressed boards. Developed in Germany by Mr. Otto Kreibaum soon after flat-pressed boards proved successful, the process spread to the United States, where for a time it kept pace with flat-pressed boards in number of installations. As in the case of flat-pressed boards, a variety of products are possible, including special boards up to 4 inches thick with hollow flutes in the center. Multi-layer boards, that is, boards composed of more than one layer, or boards of less than one-half inch thickness have not been feasible with this process.

Extruded boards are usually veneered or crossbanded before use to develop strength in the weak direction and to counteract the inherent expansion tendency induced by the pressure of extrusion. The outstanding virtues claimed for extruded boards are its greater stability in the thickness direction, which tends to reduce telegraphing problems, better screwholding properties in the edges, and lower cost.

Extruded boards may be made by either a horizontally oriented or a vertically oriented machine. In the latter case, the boards are said to have a more uniform distribution of particle sizes throughout the thickness of the board.

At the present time, there are 23 installations of the extrusion process in the United States. The Lane Cedar Co. of Alta Vista, Va., was the first to make commercial application of this method in America. They developed their own equipment for the purpose. Later, the Chipcraft Co., of Morristown, Tenn., developed similar equipment and the Dean Co. of Chicago, Ill., undertook sales of the German Kreibaum process.

3. Flat-Pressed Mixtures of Particles and Disintegrated Flakes: This is a development fostered by the successes of flake board. The mixture of flakes with typical particles imparts greater strength to the finished board in proportion to the amount of flakes. A reduction in resin content is also possible. The technique is applicable in situations where the primary raw material is planer shavings, but where a quantity of solid wood residue is also available. The first commercial application of this method was by Pope and Talbot Co., and it reportedly will be utilized by several other plants now under construction.

4. Extruded Mixtures of Particles and Disintegrated Flakes: This is a theoretical possibility only, with no known commercial application.

5. Flat-Pressed Intact Flakes: These boards are produced from flakes that are prepared and maintained as large as possible; that is, breakage along the grain is minimized during subsequent handling. In fact, the flakes carry well the impression of veneer-like elements, and the final product is capable of making a close approach to typical plywood in properties, thickness, and density. The primary virtues of these boards are high bending strength with minimum resin content. Unsanded boards have a textured surface with unusual decorative appeal. Densities lower than those for typical particle boards are also possible, and this leads to improved nailing properties.

At the present time, Pack River Lumber Co., Sandpoint, Idaho, only produces this type of board. The product, "Tenex" in ¼-inch thicknesses, has found wide use as a decorative material in both interior construction and in display fields. The flakes for this board are about 1/32 inch thick, 2 inches long, up to 1¾ inches wide, and are referred to as wafers. The raw material for the process is debarked slabs for various species. The process was developed by Dr. James d'A. Clark, presently of Victoria, B. C., with patents assigned to Changewood Corporation of Chicago, Illinois.

6. Flat-Pressed Disintegrated Flakes: Boards of this type differ from those produced from "intact" flakes in that the flakes are reduced in the width dimension. The reduction in width may occur naturally as a part of the original flaking operation, or may be accomplished as a separate milling operation. In the latter case, it is essential that the breakage occur along the grain and not across the grain. As a general rule, disintegrated flakes are shorter and thinner than the "Tenex" wafers described above. Lengths range from ½ to 1¼ inches, and thicknesses from 0.008 to 0.020 inch. Widths are variable for any given length-thickness combination, and may range from 1/16 to ½ inch.

The principal advantages of disintegrated flakes over intact flakes are greater uniformity in the particles and hence in the surface structure and internal structure of the board, and also improved handling characteristics of the particles throughout the process. For these reasons, disintegration of flakes is almost a universal practice in the manufacture of most boards, particularly if they are to be overlaid subsequently with veneer or plastic.

Following sanding or planing, these flake boards offer little in appearance to distinguish them from some types of particle board. As a general rule, the surfaces of thin flakes usually display less knife damage and are therefore more readily bonded. Furthermore, a larger number of thin flakes are required to make up the thickness of the board and this, in turn, multiplies the desirable "cross-ply" effect. From a process standpoint, it may also be noted that these larger numbers improve the chance for uniform deposition of the flakes over the area of the board during the board-forming step.

The principal disadvantages of thin disintegrated flakes lie in the fact that more energy is expended in preparation, and with the thinnest flakes, more resin is required to develop equivalent properties.

Examples of this type of board in the United States are produced by the West Virginia Pulp and Paper Co., and by the United Wood Corp. Both plants employ hammermills to disintegrate the flakes produced by disc-type flakers. A similar product produced by Columbia Hardboard Co. omits the hammermill and considers the flakes sufficiently disintegrated upon leaving a cylinder-type flaker. The raw material for this plant consists of cedar residues from adjacent shingle and lumber mills, and small red alder bolts.

The product, tradenamed "Cedawood", has a distinctive appearance as can be seen in Fig. 4. This plant is also capable of producing three-layer boards of a type to be discussed later.

The production of this type of "homogeneous" flake board in the United States is limited, but it may be expected to increase rapidly in the future. It competes directly with flat-pressed particle boards in many applications, and generally commands a premium price in exchange for higher bending strength and improved surface properties. Lower density may also be offered as a potential advantage. At the present time, there are seven plants producing or under construction to produce this type of board.

7. **Extruded, Disintegrated Flakes:** Although most extrusion processes operate with hammermilled particles, there have been two reported instances of flakes being used in an effort to achieve greater uniformity in the particles and hence in the final product. There may also be a possibility of capitalizing on the enhanced board properties engendered by the characteristics of the flakes as demonstrated in flat-pressed boards. One of the plants that uses flakes is reported in West Germany and the other is in South Africa. In the latter case, the change from hammermills to flakers was made after it was found that the local wood species were of such a high moisture content that it was impossible to hammermill them.

Two-Layer Boards

Two-layer boards are a minority group in that only a few products are represented in commercial practice. The outer layers of multi-layer boards usually contain more costly materials than the inner layer, either because of thinner flakes made from more costly wood, smaller particles, or because of higher resin content. For this reason, the special surface treatment is sometimes confined to one side only, which results in a two-layer board.

1. **Coarse-Particle Base with Fine-Particle Surface.** This is usually an unintentional, and unavoidable, outcome of a particle mix with a wide range of particle sizes. During board formation, the smaller particles sift to the bottom of the mat, where they form a distinct layer. These smaller particles may also have a disportionately higher resin content and thereby develop higher density than the balance of the board. Such a board is likely to warp excessively.

2. **Particle Base with Decorative Flake Overlay:** This type of board has not attained commercial production, but it has been produced in several pilot plants. It has possibilities as a decorative wall paneling or as a floor tile.

3. **Disintegrated Flake Base with Fine Particle Overlay:** This is a laboratory devlopment only, and has received no commercial attention. It is included primarily in the interest of completeness, but also in the interest of indicating further possibilities for development. *(Ed. Note:* Since the initial preparation of this paper, a Western Oregon firm has undertaken the manufacture of this type of board.)

4. **Disintegrated Flake Base with Decorative Flake Overlay:** This board is being produced in ¼ inch thicknesses by the Long–Bell Div. of International Paper Co. This plant developed its own process, and produced the first all-flake board in the United States. The raw material for the base layer is dry Douglas-fir mill ends, which are reduced to thin flakes on a cylinder-type flaker. The surface flakes are produced from green slabs or planks of a variety of decorative species, such as mahogany and maple, as well as local pine, western red cedar, and Douglas-fir. Marketed under the trade name of "Flakewood", it has found wide use in wall paneling, ceiling tiles, displays, and furniture.

Three-Layer Boards

Three-layer boards are presently recognized as offering the best opportunity for properties engineered to meet specific use requirements. It is in this category that maximum versatility is found, a factor traceable to the multitude of ways in which various surface materials may be combined with core materials. In addition, there are possibilities of adding more resin to the surfaces to achieve higher bending strength and greater surface stability, "pick" resistance, and edge firmness.

A further reason for the increasing popularity of three-layer boards is that they permit better utilization of available materials. For example, fines normally discarded in one-layer particle boards may be applied as top and bottom layers to produce a paintable surface or to reduce telegraphing through thin plastic overlays. On the other hand, the more tolerant core may be produced from lower-cost wood and may contain the coarser particle fractions, fractions that require the least amount of mechanical work to produce. This coarse core layer has the further advantage of aiding in the dissipation of steam generated in the center of the board during pressing.

Mr. Fred Fahrni of Zurich, Switzerland, is generally credited with the development of three-layer boards, and his "Novopan" process is licensed in a number of countries including the United States. The Behr Group in Germany has also been instrumental in advancing this method of improving board properties. They also have licensees in several foreign countries and in the United States.

From this beginning, a number of variants have emerged and doubtless many others will be forthcoming in the future. A number of three-layer products are described in the following paragraphs. It should be noted that, for the most part, these represent individual plants that are following more-or-less distinctive processes. The processes are largely controlled through patents with exclusive arrangements presently limiting the number of operating plants in each case.

It should also be noted that the greatest advances in three-layer boards have involved flakes.

1. **Fibrous Particle Center with Fibrous Fines Surfaces:** The first example of a three-layer board to appear in the United States was developed at Cascade Plywood Co., and marketed under the tradename of "Lebanite." Although this board does not fit well into any classification of composition products, it is most aptly described as a "hardboard type" particle board, but again quite different from the Rock Island "Resinwood" described earlier. It is characterized by a rather fibrous particle developed from pulp-type chips and compacted to high densities (specific gravity 1.0 or higher). Board thicknesses are ⅜ inch or less. The three layers are developed at the forming station, where the fine portion of the mix is withdrawn by suction and deposited half on the caul plate before it enters the forming machine, and half on the top of the mat as it leaves the forming machine.

The resulting board displays high bending strength, high compressive strength, high internal bond strength, and surfaces that are tough, abrasion resistant, and glossy-smooth.

2. **Coarse Particle Center with Fine Particle Surfaces:** This type of board probably has not made an appearance on the market. Attempts are being made to solve the technical problems involved, however, and it is possible that such a board may be forthcoming in the near future. The principal difficulty seems to be a means of assuring that both the top and bottom layers will be identical, an essential requirement for preventing warping.

The problem begins with the forming machine, where the top layer tends

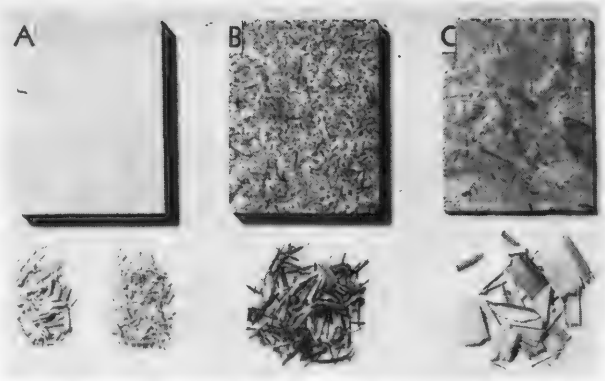

Fig. 3.—These typical flakes and boards illustrate the wide range of products available. A. Roddiscraft three-layer "Timblend", sanded. Note core flakes on left, face flakes on right. B. Columbia Hardboard Co. one-layer "Cedawood", sanded. C. Pack River Lumber Co. one-layer "Tenex", unsanded.

Fig. 4.—Typical particles and boards. A. Chipcraft extruded board. B. Cross-band veneer on extruded board. C. Wynnewood high-density board, sanded.

to sift downward into the coarse core layer. The problem is aggravated as the mat is jostled to the press, and finally is rendered uncertain during sanding or planing to thickness where further unbalance may occur.

The outstanding advantage of this board over the plain, one-layer particle board will be its improved surface properties. From a production standpoint, it would also permit a higher recovery from the raw material entering the plant.

3. Disintegrated Flake Center with Fine Particle Surfaces: This board is similar to that described in the previous section, except that disintegrated flakes are substituted for the coarse core particles. Since the flakes produce a tighter mat, the problem of sifting of the top-layer fines is immediately reduced. Hence, this type of board has greater possibilities for manufacture and should make an earlier appearance on the market. Thus far it has been produced only as a pilot-plant item in which surface qualities adequate for gloss enameling or printing have been achieved. The Columbia Hardboard Co. has recently announced a "Triplex" grade of Cedawood that would be classified in this category.

4. Coarse Particle Center with Disintegrated Flake Surfaces: This combination of particles improves the bending strength and surface properties of the conventional particle board type. Although there is no known commercial application, its manufacture would be essentially a matter of available materials. The primary raw material in this case would be planer shavings or hammermilled mill ends with a sufficient quantity of green solid material for the surface flakes. It is included here to complete the picture in regard to possible combinations of particles. This board would differ only slightly from the "Novopan" process below.

5. Coarse Particle Center with Intact Thin Flake Surfaces: This is the original Fahrni "Novopan" process developed in Switzerland. In addition to innovating the three-layer principle, the Novopan process also features a porous, splinter-type core layer that not only reduces the final board density, but also provides exit passages for the steam generated within the board during pressing. The surface layers are composed of thin, intact flakes produced from green, round wood in small disc flakers. These flakes are of high quality and are felted onto the surfaces in the original green condition after resin application.

The high moisture content of the surface flakes has a number of unique functions; 1) to facilitate compaction and consolidation of the surface layer; 2) under the action of the heat, to reduce the shrinking and swelling ability of the surface flakes; 3) to assist in carrying heat into the center of the board to accelerate the cure of the resin there.

A number of these plants are in licensed operation in foreign countries. U. S. Plywood Corp. obtained an exclusive license for this process in the United States, and the plant was installed at Redding, California. This plant, which uses peeler cores for the surface flakes, produced the first three-layer particle board in this country. Because of its greatly reduced warping tendencies, this product under the trade name of "Novoply" found immediate application as wardrobe and cabinet doors and as a core material for veneered panels.

6. Disintegrated Thick Flake Center with Intact Thin Flake Surfaces: This is an improved Novopan process recently installed in a new plant in Klingnau, Switzerland. It eliminates shavings as the core material and introduces instead a splinter-type element produced by large disc flakers. These flakers are set to produce rather thick flakes from slabs and edgings, and these in turn are reduced in a Reitz vertical disintegrator before they are dried. The resulting particles are more uniform in size and are believed to impart improved internal properties to the board. All other features of the process are similar to those of the older process.

7. Disintegrated Flakes—Thick Flake Center with Thin Flake Surfaces: This is the foundation of the Behr process developed in Germany and presently controlled by Dr. Oswald Wyss of Zurich, Switzerland. As in the improved Novopan process, all material is produced by disc-flaking solid wood. The primary difference is that *both* the core flakes and the surface flakes are disintegrated.

Other important differences are in the sizes of the flakes. For example, in the Behr process, the core flakes are thinner and the surface flakes are shorter than in the Novopan process. One of the notable features of the Behr process is the great care exercised to insure the elimination of potential telegraphing particles from the surface layers. This is accomplished by means of an air classifier, which is capable of screening flakes on the basis of thickness.

The Behr process has been licensed in Germany and other countries. Exclusive rights for this process in the United States have been obtained by Roddis Plywood Corp. The plant was installed at Arcata, California, and production of their "Timblend" line began in 1957.

A unique variation of the conventional three-layer processes has been developed by the Baehre Metallwerk KG of Springe, Germany. This process eliminates all duplicate equipment usually necessary to prepare core and

surface material separately, such as flakers, screens, dryers, mixers, storage chests, and forming stations. The key item of equipment in the Baehre process is the forming machine, which takes the entire output of the flakers, with the exception of the dust, and converts it into a three-layer mat. This is accomplished by means of a regulated air stream that deposits the finer fractions as top and bottom layers surrounding a coarse core layer. As a consequence of this air-felting system, the particles, or flakes, grade in size gradually from the center to the surface, thus assuring fine-textured surfaces with minimum tendency for telegraphing into overlay materials.

8. Intact Flakes—Thick Flake Center with Thin Flake Surfaces: This is another of the "Tenex" line of the Pack River Lumber Co., developed by Dr. James d'A. Clark and licensed through Changewood Corp. The product features intact flakes or wafers throughout, and develops relatively smooth surfaces by means of outer layers of thin wafers. All wafers are produced from debarked slabs by means of cylinder-type flakers or "waferizers". A dry powdered phenolic resin is used as the binder, a unique feature of the process. Produced in ¼-inch thicknesses, the outstanding use has been for interior wall paneling.

Trends

By way of conclusion, it may be well to recognize two notable trends appearing throughout the world in this industry. The first is a strong trend in the direction of flakes or other specially prepared elements, and away from the nondescript particle. The second is a trend toward multilayer boards that have faces and cores in the manner of plywood.

Both of these trends are in the direction of higher cost products with improved properties. These trends presage a demand for this type of product in its own right, a wood product peculiarly adaptable to the whims and needs of the consumer.

As this new role is assumed more firmly by the board industry, it is to be expected that its older role of abatement of the problem of residue wood will decline. How far this trend may reach in the direction of sawlogs and pulpwood is debatable, but it seems certain that it will find a normal equilibrium on the basis of economics. It may well have an influence, for example, on the proportion of low-quality lumber produced from low-quality logs. In addition, stand-improvement cuttings and logging of so-called inferior species specifically for board production will undoubtedly increase.

From the description of the various board types, it may be seen that the complexity of the particle board industry is generated by its own versatility. Since it is still in its infancy, it is difficult to predict whether future ingenuity will make it even more complex, or whether certain board types will emerge dominant and overshadow all others.

INVESTIGATE THIS PRACTICAL, LOW-COST

Roof Framing for Light Buildings

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Light, economical roof trusses can be erected with tractors or even by hand. Standard spans and slopes make accurate lumber-yard fabrication possible. The glue-nail truss will hold four times the design load.

The need for economical farm and light commercial buildings is becoming more critical as the margin of profit for farm produce becomes less. Past conventional methods of construction were usually high in first cost, and the buildings do not lend themselves to modern operations. This is a report of research on the design of a system of construction that has minimum cost and maximum quality. The objectives of the research have been:

1. To develop a low-cost construction system for farm or light commercial buildings.
2. To make the system adaptable to prefabrication or prepackaging so

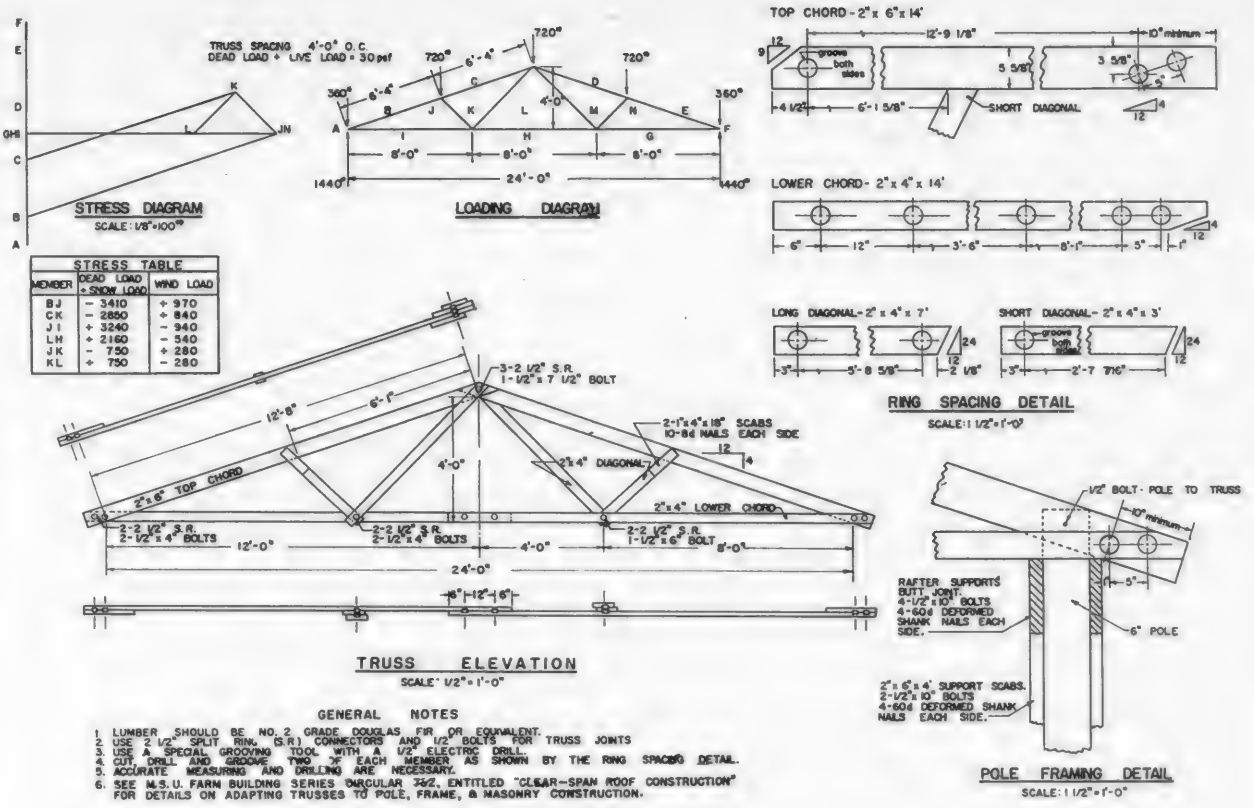

TRUSS SPACING 4'-0" O.C.
DEAD LOAD + LIVE LOAD = 30 psf
STRESS DIAGRAM
SCALE: 1/8"=100#
LOADING DIAGRAM
STRESS TABLE
MEMBER | DEAD LOAD + SNOW LOAD | WIND LOAD
BJ | - 3410 | + 970
CK | - 2850 | + 840
JI | + 3240 | - 940
LH | + 2160 | - 540
JK | - 750 | + 280
KL | + 750 | - 280
TOP CHORD - 2" x 6" x 14'
LOWER CHORD - 2" x 4" x 14'
SHORT DIAGONAL
LONG DIAGONAL - 2" x 4" x 7'
SHORT DIAGONAL - 2" x 4" x 3'
RING SPACING DETAIL
SCALE: 1 1/2"=1'-0"
3-2 1/2" S.R.
1-1/2" x 7 1/2" BOLT
2-1"x4"x18" SCABS
10-8d NAILS EACH SIDE
2"x6" TOP CHORD
2"x4" DIAGONAL
2"x4" LOWER CHORD
2-2 1/2" S.R.
2-1/2"x4" BOLTS
1-1/2"x6" BOLT
TRUSS ELEVATION
SCALE: 1/2"=1'-0"
1/2" BOLT - POLE TO TRUSS
RAFTER SUPPORTS BUTT JOINT.
4-1/2"x10" BOLTS
4-60d DEFORMED SHANK NAILS EACH SIDE.
6" POLE
2"x6"x4' SUPPORT SCABS.
2-1/2"x10" BOLTS
4-60d DEFORMED SHANK NAILS EACH SIDE.
POLE FRAMING DETAIL
SCALE: 1 1/2"=1'-0"
GENERAL NOTES
1. LUMBER SHOULD BE NO. 2 GRADE DOUGLAS FIR OR EQUIVALENT.
2. USE 2 1/2" SPLIT RING (S.R.) CONNECTORS AND 1/2" BOLTS FOR TRUSS JOINTS
3. USE A SPECIAL GROOVING TOOL WITH A 1/2" ELECTRIC DRILL.
4. CUT, DRILL AND GROOVE TWO 2" EACH MEMBER AS SHOWN BY THE RING SPACING DETAIL.
5. ACCURATE MEASURING AND DRILLING ARE NECESSARY.
6. SEE M.S.U. FARM BUILDING SERIES CIRCULAR 342, ENTITLED "CLEAR-SPAN ROOF CONSTRUCTION" FOR DETAILS ON ADAPTING TRUSSES TO POLE, FRAME, & MASONRY CONSTRUCTION.

Fig. 1.—A plan showing the design and layout features for the split-ring trusses.

lumber dealers could use it as a selling tool.

3. To make the system simple enough so farmers or unskilled laborers could do the work themselves if necessary.

Wood is the most-used construction material on farms and is universally available, but because of inefficient fasteners, it is being replaced by other materials. Normally in pole or post wood-frame construction, the distance between interior post supports has been limited to 15 or 16 feet by the size of readily available wooden joists or girders. Clear-span construction is being used in heavy commercial buildings, but due to relatively higher costs, it has not been applied to farm or other light-weight structures. It is very desirable for farm buildings, however, because it allows free movement of machinery and animals. In storage structures or lumber sheds, where materials are handled by machine, the absence of poles facilitates operations.

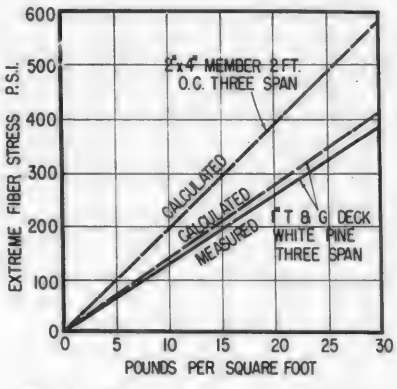


Fig. 2.—The load versus stress curves for two systems of roof deck.

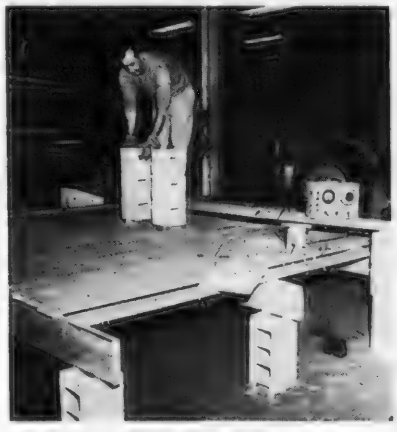


Fig. 3.—Testing apparatus for determining stress and deflection on one-inch roof sheathing.

Determination of Design Conditions

To provide clear-span areas, some form of truss is necessary. An analysis of plans showed that four widths, 24, 30, 36, and 40 feet, would be satisfactory for nearly all farm buildings. These widths are also suitable for lumber sheds, storage buildings, 4H exhibit buildings, and so forth. A 4/12 roof slope was also selected. This resulted in four designs that could be used generally for all buildings. Standardizing on just four plans made the resulting system attractive to lumber dealers.

An analysis of plans from different plan services indicated that truss spacings of four feet to six feet are most economical in cost per square foot of area covered. This spacing was wider than normally used for rafters and less than commonly used for roof trusses. The trusses designed for the four-foot spacing were light weight and could be erected easily with farm tractors. Roof-deck framing presented a problem because conventional plans use rafter spacings of 24 inches. By using a four-foot spacing, some adjustment was considered necessary in the roof deck to allow for this wider spacing.

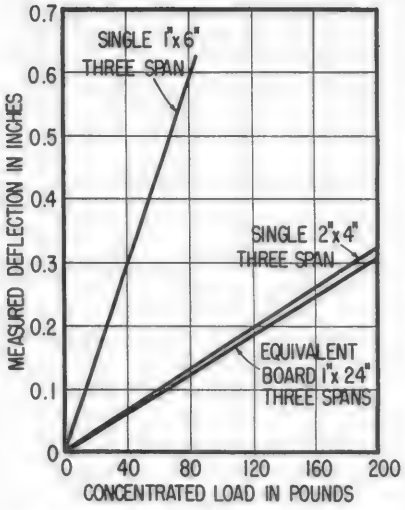


Fig. 4.—The load-deflection curves for the roof decks under test.

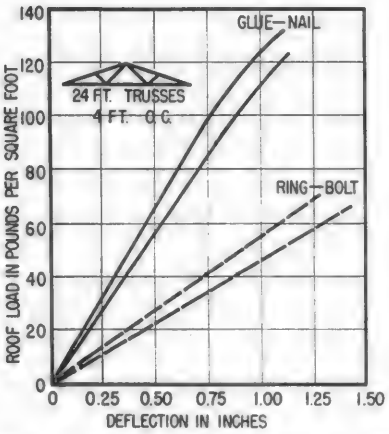


Fig. 5.—The load-deflection curves for the 24-foot glue-nail and ring-bolt trusses.

Tests were run to determine what types of roof deck could be used. Fig. 2 shows the relation between a uniformly distributed roof load and the resulting fiber stress for two types of deck. The fiber stress was measured by SR-4 electric resistance strain gages. The loading procedure shown in Fig. 3 represents a concentrated load applied at the center of the span, which would simulate a man walking on the roof. Fig. 4 shows the relation between the concentrated loads and deflection. Similar fiber stresses were also calculated and found to be slightly higher than the measured stresses.

These data show that either 2- by 4-inch members spaced 24 inches on center or 1-inch tongue-and-groove boards could be used as a roof-deck without exceeding the safe design stress or safe deflection limits. The curve for a 1- by 6-inch board is the condition prevailing if unmatched boards are used. A 40-pound load on this single-board type of deck caused a deflection of 0.3 inch, which is equal to that caused by a 200-pound load on the 1- by 24-inch board as extrapolated from the 1- by 6-inch tests. The deflection on the solid tongue-and-groove deck proved to be approximately the same as that on the 2- by 4-inch members spaced 24 inches on center.

Fasteners Used in the System

Efficient fasteners for wood are available and generally used in commercial construction. These fasteners, however, are not generally available and consequently not used in farm buildings. The two types of fasteners considered in this investigation were split rings and glue with nail pressure. To be of use in practice, the fasteners must be available locally through normal suppliers. After considerable education on the part of farmers as users and industry as suppliers, it was found that split-rings and casein glue in bulk could be made available through local lumber deaers. With these fasteners, expense of the joints could be reduced substantially over nailed construction of similar strength.

Performance Tests on Trusses

The performance tests were on 24-foot trusses with 2- by 6-inch top chords and 2- by 4-inch web members. A typical plan for the split-ring and bolt truss is shown in Fig. 1. Casein glue with $\frac{5}{8}$-inch plywood gusset plates nailed with 6d box nails was used in the glue-nail truss. Loads were applied at two-foot intervals along the top chords, and deflections were measured with dial indicators. Representative load-deflection curves for the two truss designs are shown in Fig. 5.

These tests show that the glue-nail truss is about twice as strong as the ring-bolt truss, although both designs are adequate for farm buildings. The deflection in the glue-nail design is approximately one-half as much as in the ring-bolt designs. The total deflection at time of failure was nearly the same for both designs, being slightly more than one inch at the ridge.

Most of the failures occurred in the heel joints of the ring-bolt truss. A typical failure is shown in Fig. 6.

Limited tests were run on glue-nail trusses made with $\frac{1}{2}$-inch plywood, but failure occurred consistently in the heel joint, as shown in Fig. 7. As a result, all designs specify $\frac{5}{8}$-inch plywood as gusset plates. The glue-nail trusses with $\frac{5}{8}$-inch plywood failed in different members during the tests,

Fig. 6.—A heel-joint failure typical of failures in the split-ring trusses.

Fig. 7.—A representative type of failure when $\frac{1}{2}$-inch plywood was used in gusset plates.

which indicates a more balanced design. None of the glued joints failed along the glue line.

Summary

1. Trusses designed for four-foot spacing provide a light, economical, roof frame that is easily fabricated and erected by both builders and farmers with farm tractors.

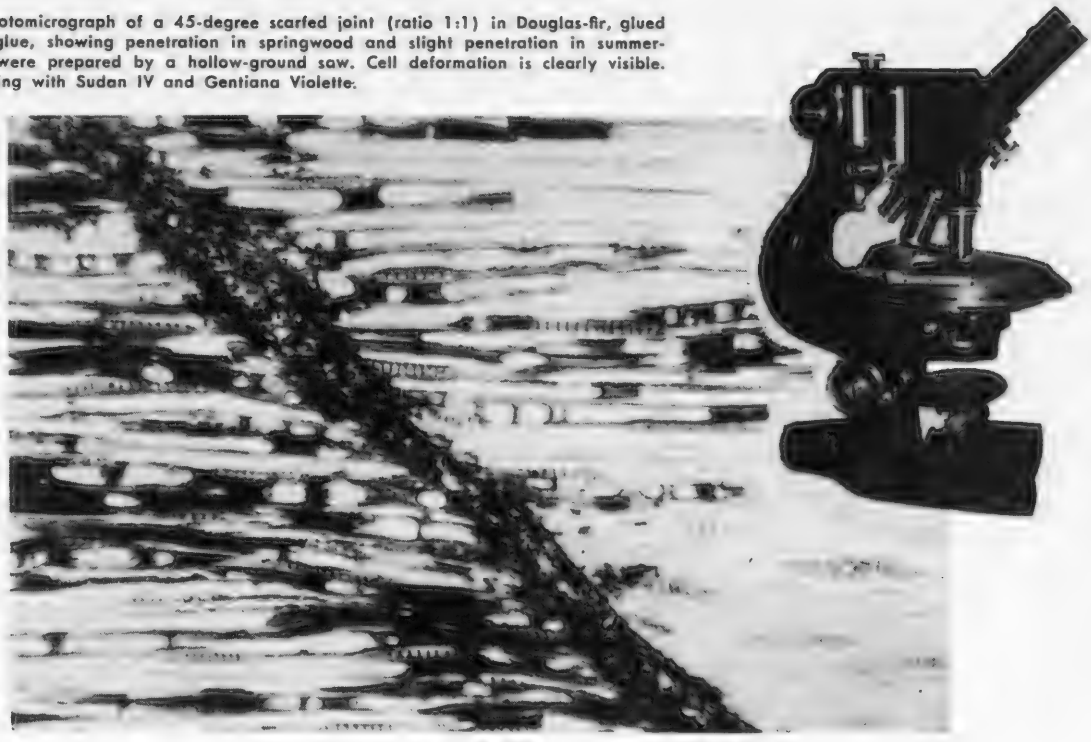
2. Standardization of spans at 24, 30, 36, and 40 feet and slopes at 4/12 provides buildings that meet the requirements for most farm and light commercial uses. This makes lumberyard fabrication practical and a method of getting good construction.

3. A solid, one inch tongue-and-groove deck or an open deck with 2- by 4-inch girts, 24 inches on center, allows a factor of safety of at least four with a design load of 30 pounds per square foot.

4. Deflection for a one-inch tongue-and-groove roof deck under a concentrated load of 200 pounds is 0.3 inch, which is satisfactory for the intended applications.

5. A glue-nail truss will hold an ultimate load of four times a 30-pound-per-square-foot design load. The ring-bolt truss will hold two times the design load of 30 pounds per square foot.

Fig. 1.—Photomicrograph of a 45-degree scarfed joint (ratio 1:1) in Douglas-fir, glued with resorcinol glue, showing penetration in springwood and slight penetration in summerwood. Surfaces were prepared by a hollow-ground saw. Cell deformation is clearly visible. Differential staining with Sudan IV and Gentiana Violette.



SURFACE TEXTURE OF WOOD AS RELATED TO

Glue-Joint Strength[1]

J. E. Marian, D. A. Stumbo, and C. W. Maxey

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Surface roughness has little effect on joint strength. Adhesive joint properties are more important. The real problem, however, is strength reduction caused by contact of springwood with summerwood.

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THE TEXTURE AND SHAPE OF WOOD surfaces, methods of quantitative measurement, and the significance of surface characteristics in relation to glue joint strength for edge-wood and end-wood gluing are the concern of this paper.

For a number of years the author and his co-workers attempted to relate surface texture and anatomic structure to joint strength in gluing wood edgewise (1, 2)[2, 3]. This paper presents the main results obtained from research in Sweden and a first report of studies carried out in this Laboratory on the significance of surface texture for end-wood glued joints.

Surface Texture of Wood

Various unique properties of wood make the measurement of its surface texture difficult. The relevant problems are discussed in a study to be published at a later date (1).

In edge-wood as well as in end-wood, there are several distinct degrees of surface textures of varying magnitude, superimposed.

An absolutely smooth cut in wood should yield, on a microscopic scale, a surface formed only by anatomic structure. Such a surface can be produced experimentally, with a fair degree of approximation, by cutting with a microtome. This might be called a first-degree texture. On this scale, summerwood and springwood will have different textures (Fig. 4 d and e), as will surfaces cut parallel to the grain (Fig. 2) and across the grain (Fig. 3).

On a magnification scale of 1,000 X, even microtome-cut surfaces can hardly be called smooth; rather, they are compound, as shown by texture graphs in Fig. 4 d and e. The compressibility and resiliency of spring-

[1] Presented at Session VIII, Glues and Gluing, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

[2] The authors gratefully acknowledge the friendly cooperation of Bengt Norén of the Swedish Forest Products Research Laboratory, Stockholm. His ideas derived from discussions have materially contributed to the development of this program and to its findings.

[3] Numbers in parentheses refer to the Literature Cited.

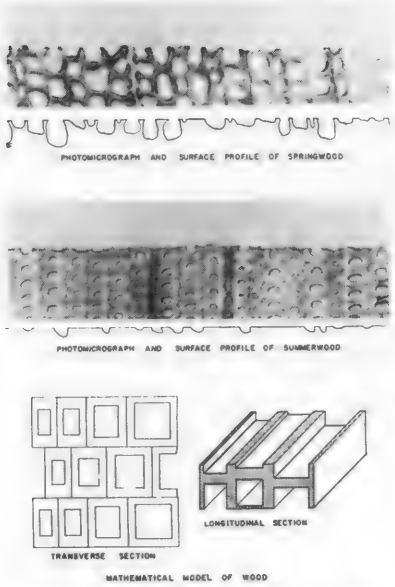

PHOTOMICROGRAPH AND SURFACE PROFILE OF SPRINGWOOD
PHOTOMICROGRAPH AND SURFACE PROFILE OF SUMMERWOOD
LONGITUDINAL SECTION
TRANSVERSE SECTION
MATHEMATICAL MODEL OF WOOD

Fig. 2.—Photomicrograph and surface profile in springwood and summerwood of Scotch pine *(Pinus sylvestris)* from Sweden; model concepts in edge-wood gluing according to K. Suchsland (2).

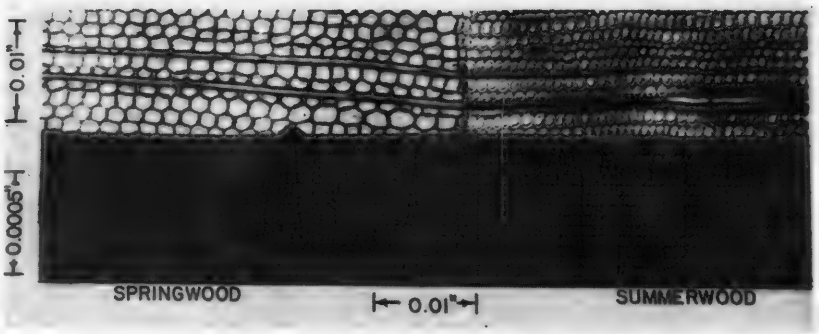


Fig. 3.—Photomicrographs of Douglas-fir springwood and summerwood transverse surfaces with texture graphs at the same magnification.

wood in comparison with the relatively stiff summerwood account for this. After it is cut with the microtome knife, the springwood recovers from an elastic deformation caused by cutting pressure. No significant deformation takes place in the stiff-walled summerwood. These differences in cutting characteristics are shown in Fig. 4 d and e.

A second degree of texture will be produced through the different cutting (machining) characteristics of wood, especially of springwood and summerwood. Inherent machining variables (mode of cutting, tool sharpness, cutting speed, feed velocity, moisture, and so forth) yield different surfaces. Sawing gives a surface different from planing, as do sanding and slicing. Surface texture is a function of a multitude of variables connected with mechanical preparation. Examples are given in Fig. 4, a, b, and c.

Recently it has been shown, qualitatively at least, that anatomic structure is disturbed to varying degrees (7). Cells or fragments of cells, or tissues, are torn out from the wood structure by the action of tools, or cell cavities may be closed with debris from sanding, or by permanent cell-wall deformation through impact. The mechanical weakening of the surface layer of wood as a consequence may be assumed[1].

[1] Exploratory tests (microtensile strength specimens cut out of the damaged surface layer) make it highly probable that this weakening actually occurs, but results are not yet conclusive. The significance of this for fiber percentage as a criterion of glue joint strength is evident.

A third degree of texture will be produced by *incidental* machining variables, such as uncontrollable machine vibrations, wild teeth in saw blades, damaged or worn tool edges, and so forth, or by incidental variations in the wood material, such as growth-ring density, compression wood, and resin pockets. Differentiation of these surface texture influences and analysis of their significance for results in gluing are extremely difficult, but are of fundamental importance in considering the problems of adhesion in wood and especially of end-wood gluing.

Four methods were used to check the dimensional accuracy and surface texture of mating surfaces:

1. Surface profile measurements derived from highly enlarged microphotographs (2) (Fig. 2).
2. Surface texture measurements with a stylus-type tracer instrument, which enlarges roughness data electronically and records them permanently (Figs. 3 and 4).
3. Determination of the degree of approximation—"trueness of angle"—of the proper geometric position of the surface as a whole, by means of the instrument shown in Fig. 6 a.
4. Measurement of the deviation of certain points in the surface from the ideal geometric plane—"trueness of surface"—by means of the instrument shown in Fig. 6 b.

Roughness Factor, Porosity, and "Fill-in"

As a criterion of microscopic surface texture, a "roughness factor," R, can be chosen where $R = A_r/A_p$.

Cross-sections of wood will not give a continuous surface, but something resembling a perforated plate of definite porosity, as shown in Figs. 2 and 3. Porosity will depend mainly on cell-wall thickness relative to cell-lumen dimension, and can be defined as the ratio of pore volume to total volume. If a simplified and idealized wood structure consisting of a series of rectangular tubes is assumed as a mathematical model, then porosity can be defined as "surface porosity" $= P = \frac{A_p}{A}$.

For the ratio of wood volume to total volume, or for the area of cut

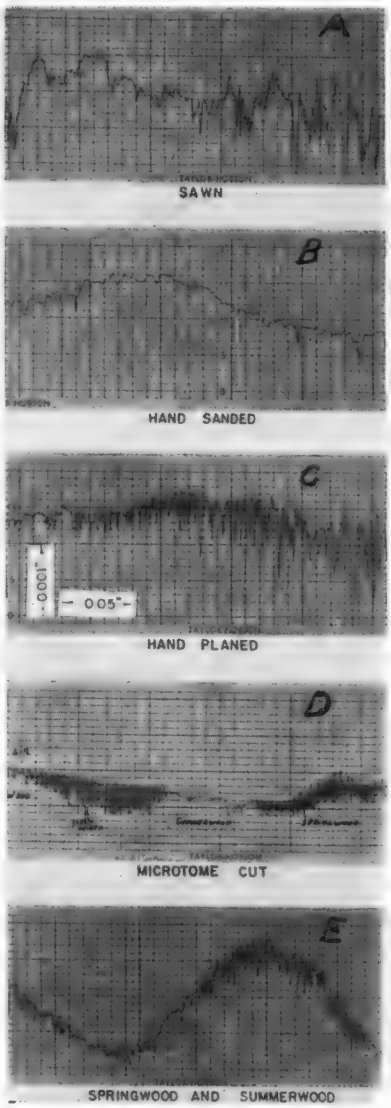


Fig. 4.—Texture graphs of surfaces produced by different methods on end-grain Douglas-fir: Slow-grown (d) and fast-grown (e) were both microtome cut.

wood substance to total cross-section we can introduce:

$$F = \frac{A - A_p}{A} = \frac{A_w}{A}$$

where A_w = area of cross-cut wood substance and F = "fill-in."[5] R, according to these definitions, always has a value larger than 1, and $F + P = 1 = 100\%$. F can also be defined as cell-wall fraction.

These concepts have been applied to a study of the influence of surface roughness on edge-wood gluing. The relationship between porosity, surface texture (roughness determined from photomicrographs of tangential sections), and shear strength of tangentially glued specimens was determined for edge-glued joints of Scotch pine *(Pinus sylvestris)* from Sweden (2).

[5] "Fill-in," $F = 1 - P$ or $F + P = 1$. Synonyms such as inporosity, concretion, solidity, woofiness, spatial occupation, are clumsy and equally unsatisfactory; cut wood substance lacks the abstraction conveyed by the term porosity.

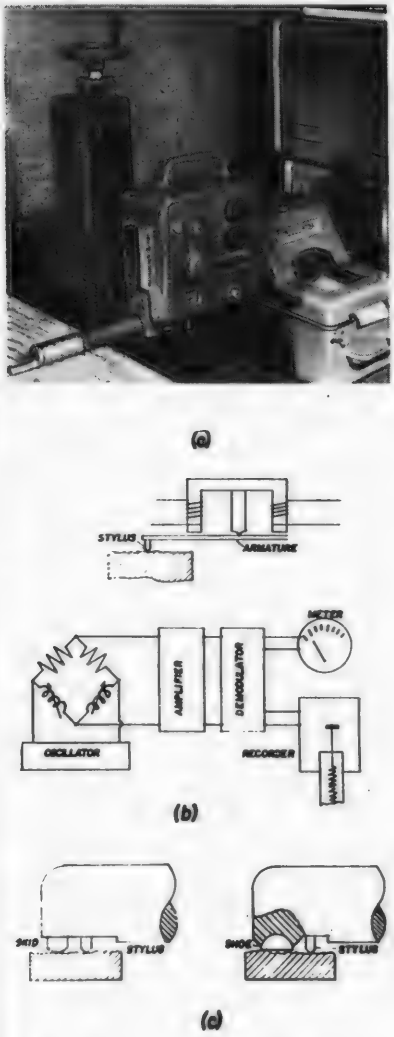


Fig. 5.—(a), Stylus tracer instrument; (b), electric principle of carrier modulating instrument; (c), datum—skid and shoe—and stylus.

The results show that the strength of these joints increased with increasing surface roughness until the point was reached at which the simultaneously decreasing strength and increasing porosity caused the wood to break. Beyond this point, an increase in roughness diminished the shear strength of the joint.

This behavior of wood is in agreement with that of nonporous materials such as metals, for which the surface roughness-shear strength curve shows a definite maximum (For details and data, see (1) and (2). The same concepts have been applied to some of the problems in end-wood gluing.

The factors R, F, and P can be determined experimentally by different methods:

1. From a photomicrograph of the wood surfaces in incident light at high magnification, as done for tangential cuts by K. Suchsland (2) or for microtome sections by Morschauser (3).
2. From the graphs of an electronic tracer instrument (1, 4, 5).
3. From the Kollmann-Trendelenburg graph relating density, P and F (6).

WHAT THIS RESEARCH MEANS

Wood has been bonded since time immemorial—laminated veneered products were found in the tombs of the Egyptian Pharaohs—but up to now has only been joined *edgewise*, the direction in which the shear strength of wood is *lowest*.

End joining of wood by means of *simple* joints—short scarfs, butt-end or wedge type—so far has only been the pipe dream of a few.

The question is: Can the original strength of wood, in the grain direction, be restored—as has been done for ages in edge gluing? To answer this question, we need to know more about the influence of surface roughness (texture), wood structure, and the strength and elastic properties of the adhesive joint.

The influence of surface roughness is slight, that of wood structure and glue properties decisive—as found in this investigation. The strength of clear, solid Douglas-fir, for instance, is mostly determined by its summerwood. It is found that springwood can be glued, but not summerwood. The contention is that the adhesion of glues is good enough for edge gluing, but in simple end joints does not match the strength and elastic properties of wood. The search is on for a better adhesive and bonding procedure, which may mean in time a simpler, cheaper, and more efficient solution of end-wood jointing problems. This time perhaps practice is not ahead of theory by more than a nose.

Editor

In many ways, electrical methods are the most practical for the numerical assessment of surfaces. The instrument used[6] gives permanent records; the stylus, a four-sided 90-degree pyramid with a spherical tip of 2.5-micron diameter, bears on the surface with a force of only about 100 milligrams. It is of the carrier modulating type. Mechanical displacements are converted into electrical currents so that the magnitude of the carrier current is controlled instantaneously by the position of the stylus relative to the datum, regardless of how long the stylus remains in a given position.

Carrier modulating instruments are to be preferred for obtaining graphical records, because they faithfully reproduce every movement of the stylus relative to a datum (the skid or shoe), regardless of the spacing of the crests, that is, of the rate of rise and fall of the stylus. Fig. 5 illustrates the instrument used. Details may be found in the literature (4, 5).

The instrument, as illustrated by graphic records, is sufficiently sensitive for the tracing of structural anatomic details (Fig. 3), and thus can be used to determine cell dimensions, derive

[6] Talysurf, Taylor, and Hobson, Leicester, England. Engis Equipment Co., Chicago, Illinois.

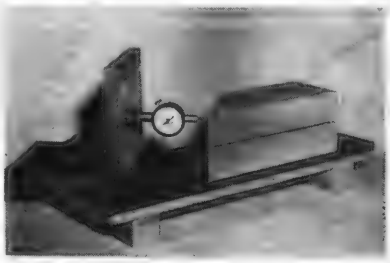


Fig. 6a.—Instrument used for measurement of "trueness of angle."

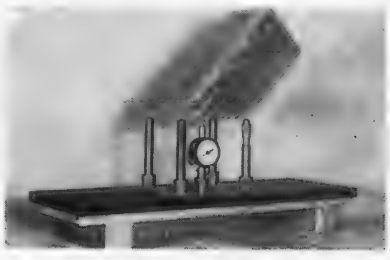


Fig. 6b.—Instrument for measurement of "surface trueness." Three fixed points in the surface to be glued define a plane; the fourth adjustable point (at right) measures any deviation from this plane. Dial is movable along a grid of coordinates spaced 10 mm. apart, and measures deviations of a surface to 0.001 inch. Surface trueness is computed by first averaging all measurements (+ or — separately) for two surfaces to be mated, then taking the absolute (arithmetic) mean of the two means. Thus, surface trueness index is the average mean deviation of two surfaces to be glued, from a defined plane.

R, F, and *P,* and indicate springwood-summerwood distribution within growth rings (Fig. 4 d). Without accessory equipment, its resolution is too fine for certain technically less-important, rough-surface types, such as sawn surfaces.

Fig. 4 illustrates the differences in texture produced by sawing, hand-planing, sanding, and microtome cutting of Douglas-fir end-grain, as recorded by the electronic tracer instrument.

Area of Contact

Wood, as an elasto-plastic body, will, in general, behave in a way analogous to that of metals. This means that two wood surfaces brought into contact for gluing will have a *small actual area of contact.* This area will vary with surface textures and the load-gluing pressure, and actually might be only a fraction of the apparent geometric, nominally measured area. This means that, even with slightly loaded surfaces, the local pressure at these small points of contact is very high, and may be sufficiently great to cause even hardwood to flow plastically.

Although the stresses will cause elastic deformation of the wood in the vicinity of the points of contact, experience suggests that the summits of irregularities on which wood surfaces are supported flow plastically, and are deformed until their cross section is sufficient to support the applied load. Actually, we are able to demonstrate this behavior in photomicrographs of glued joints[7], but so far have not been able to resolve the problem satisfactorily either experimentally or mathematically.

De Riberolles, working in this Laboratory, has been able to demonstrate a certain surface deformation by the very process of machining, itself (7).

These observations suggest a concept of a "contact factor" that would define the actual mathematically assessable area of *contact of surfaces,* especially in end-wood gluing under definite pressures. This problem will be dealt with on a microscopic scale in a later part of this study.

Experiments with Short Scarfs and Butt-end Joints

In our applied studies on end-wood gluing of Douglas-fir (short scarfs and butt-end glued joints), we have attempted to obtain extreme dimensional accuracy, and have developed methods of measuring what we call "trueness of angle" and "trueness of surface," that is, the degree of approximation to the desired, ideal, geometric shape and plane.

"Matched" pieces were used (disregarding the saw kerf). Members were aligned (springwood joined to springwood and summerwood to summerwood) in scarfed joints; aligned and misaligned (springwood joined to summerwood and summerwood to springwood), in butt-end glued joints.

Surprisingly, the roughest surface, as measured by the "center-line average" of graphic records, produced the strongest joint (Table 1). The surfaces prepared by a hollow-ground saw showed the greatest deviation from the ideal plane.

In similar experiments by de Riberolles (7), butt-end joints were produced under identical conditions. Tensile and impact bending figures correspond with those obtained for scarfed joints, and surfaces prepared by a flat-ground saw again gave the strongest joints (see Table 2).

In a series of experiments, springwood was glued either to springwood or to summerwood, or, in a third case, the two were "crossed." The averages of four specimens in each case gave the following means:

Springwood with Springwood	Springwood with Summerwood	"Crossed:
1,341 psi	1,460 psi	1,360 psi

From these averages of the five types of surface preparation (flat and hollow-ground sawn, machine- and hand-planed, band-sanded), it might be concluded that positioning of growth rings has no apparent effect on joint strength.

[7] Sections and slide were prepared by Wayne W. Wilcox of the School of Forestry at the University of California, Berkeley.

Definitions of Terms Used

A_r	Real surface area, formed by cut cell walls and troughs of cut cells
A_g	Geometric surface area (nominal measured area for surfaces cut parallel to the grain)
R	Roughness factor $= A_r/A_g$
P	Porosity or surface porosity $P = A_p/A$
A_p	Area of cross-sectioned pore space
A	Area of total cross section
A_w	Area of cross-cut wood substance
F	Cell wall fraction "fill-in" $F = \frac{A - A_p}{A} = A_w/A$
σ	Unit tensile stress
σ_{Ru}	Unite tensile stress at rupture when wood is at u moisture content
τ	Unit compression stress
τ_{Ru}	Unit compression stress at rupture when wood is at u moisture content
σ_{Rspu}	Unit tensile stress of springwood at rupture, at moisture content u
τ_{Rsu}	Unit compression stress of summerwood at rupture, at moisture content u
τ_{Rspu}	Unit compression stress of springwood at rupture, at moisture content u
s	Summerwood fraction in growth rings
r	Density of wood
r_{spu}	Density of springwood at moisture content u
r_{su}	Density of springwood at moisture content u
m.c.u.	Moisture content u
e.m.c.u.	Equilibrium moisture content u
F_s, F_{sp}	Cell wall fraction "fill-in" of summerwood and springwood, respectively
S_1, S_2, S_3, S_4	Probabilities, $1 = S_1 + S_2 + S_3 + S_4$
C.L.A.	Center line average
h_{CLA}	$\frac{1}{L}\int_0^L /y/\ dL$
	Center line is the line for which the sum of the squares of equally spaced ordinates is a minimum.

Influence of Springwood and Summerwood on Glue Joint Strength

Experiments have been conducted in this Laboratory on the growth-ring laminary structure of wood—the contribution of springwood and summerwood to the total strength of wood and of end-glued wood. Care was again taken to align the members accurately (neglecting the saw kerf). Results of some of the work to date are summarized in Fig. 7.

In the authors' opinion, the basic problem in end-wood gluing is the transmission of stresses between springwood and summerwood, both of which have entirely different densities, strength, and elastic properties when bonded adhesively.

The contribution of springwood and summerwood to total wood strength has been theoretically and experimentally derived by Ylinen (8) for Scotch pine *(Pinus sylvestris)* from Finland. The relevant basic equation for tensile strength is:

$$\sigma_{Ru} = \sigma_{Rspu} + (\sigma_{Rsu} - \sigma_{Rspu})s,$$

and for compression strength:

$$\tau_{Ru} = \tau_{Rspu} + (\tau_{Rsu} - \tau_{Rspu})s,$$

Because no similar investigation could be found for Douglas-fir, a few exploratory tests were run in connection with the gluing experiments. For the particular material used, the average figures were:

$s = 0.35$ (35%) summerwood fraction
$\sigma_{Rspu} = 3{,}600$ psi
$\sigma_{Rsu} = 15{,}300$ psi
$r_{spu} = 0.21$
$r_{su} = 0.55$

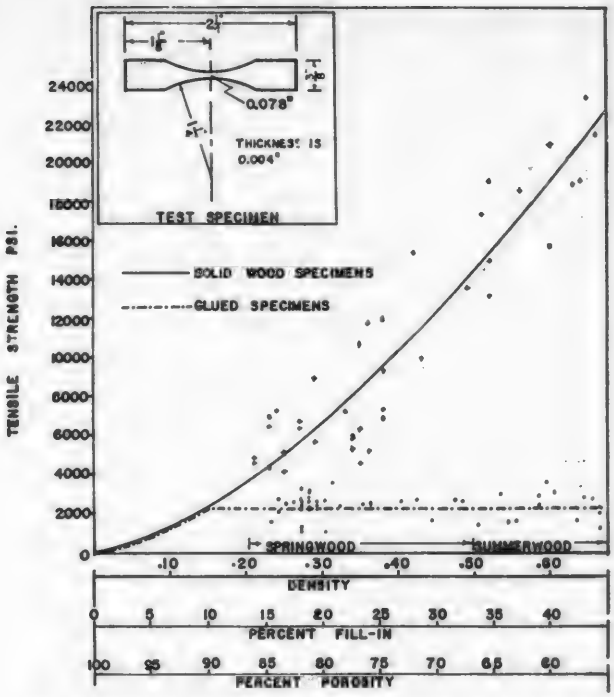


Fig. 7.—Selected blocks of Douglas-fir of about ½ by 2½ by 2 inches were surfaced by microtome cutting perdendicularly across the grain and conditioned to e.m.c. = 11%. Resorcinol glue spread was approximately 0.5 cc. per square inch, distributed on both surfaces from a surgical syringe. After 5 minutes open TA, a second spread was applied. Pressure of approximately 150 psi was applied after a closed TA of 30 minutes. Curing followed in an air oven at 180° F. ± 5° for 24 hours ± 1 hour.

Microtest specimens were prepared by die-stamping microtome-cut sections; specimens were reconditioned to 11% e.m.c. for testing on the Instron tester and tested under constant temperaure conditions 76° F. ± 2.5° and e.m.c. = 10% ± 1%. Dots represent glue joint strength individual figures, crosses solid wood strength data.

$_u$ = moisture content—11%
r_{spu} = density springwood at u
r_{su} = density summerwood at u

from which it follows:

σ_{Ru} = 7,695 psi
σ_{Ru} = tensile strength of wood at rupture at m.c.u.
τ_{Ru} = compression strength of wood at break at m.c.u.

Numerically this means that springwood contributes about 30 per cent and summerwood about 70 per cent to the total strength, although the summerwood fraction ($s = 0.35$) is only 35 per cent of the total wood.

If we assume that density is proportional to strength (3, 10), and that the elongation at rupture is identical for springwood and summerwood (as ascertained by Ylinen (8), this means that adhesion between summerwood and glue has to be about twice as strong as between springwood and glue.

Several surprising results are shown in Fig. 7.

1. In most cases, in springwood joints it is possible to achieve approximately the full strength, or 100 per cent, of the springwood; in summerwood, only about 10 to 15 per cent. *Incidentally*, the strength of summerwood-summerwood joints is about the same as that of springwood-springwood joints.

2. This is the case in spite of the fact that the glued area "cut-wood sub-

Table 1.—TENSILE, COMPRESSION, AND IMPACT BENDING STRENGTH OF 45° SCARFED JOINTS IN DOUGLAS-FIR MATCHED SAMPLES. RESORCINOL GLUE, HIGH-FREQUENCY SETTING

SURFACE PREPARATION	SURFACE MEASUREMENTS		TEST		
	C.L.A. TANGENTIALLY	SURFACE TRUENESS INDEX	TENSION OBLIQUE P.S.I	TOUGHNESS INCH POUNDS	COMPRESSION OBLIQUE P.S.I.
FLAT GROUND SAW	200+	2.26	1720	18.5	5510
HOLLOW GROUND SAW	185	4.03	1310	11.8	5504
MACHINE PLANED	150	2.04	1480	9.4	5210
HAND PLANED	100	1.40	1410	8.9	5740
SANDED	135	1.83	1660	15.1	5900

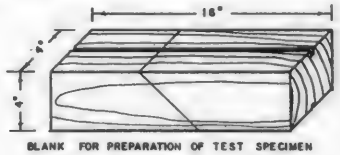
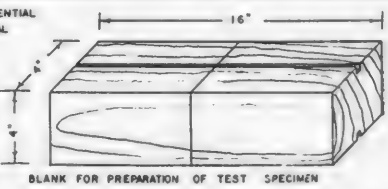


Table 2.—TENSILE AND IMPACT BENDING STRENGTH OF BUTT-END JOINTS IN DOUGLAS-FIR MATCHED SAMPLES. HIGH-FREQUENCY SETTING RESORCINOL GLUE (7).

SURFACE PREPARATION	SURFACE MEASUREMENTS		TEST	
	C.L.A TANGENTIALLY	SURFACE TRUENESS INDEX	TENSION PERPENDICULAR P.S.I	TOUGHNESS INCH POUNDS
FLAT GROUND SAW$_1$	200+	1.3	1716	14.1
FLAT GROUND SAW$_2$	200+	1.7	1694	12.6
HOLLOW GROUND SAW$_1$	180	3.2	974	6.7
HOLLOW GROUND SAW$_2$	160	3.6	887	7.7
MACHINE PLANED$_1$	145	1.0	1437	8.9
MACHINE PLANED$_2$	130	0.5	1480	11.3
HAND PLANED$_1$	120	1.9	1555	10.3
HAND PLANED$_2$	130	0.8	1549	9.3
SANDED	120	1.7	1201	10.9

1 CUTTING ACTION TANGENTIAL
2 CUTTING ACTION RADIAL



Computation: Total load P divided by actual area of glue line.

Number of specimens:

Compression: 25 (2" x 2") 1 specimen per blank
Impact bending (toughness): 40 (0.79" x 0.79") 4 specimens per blank
Tensile: 40 (1" x 1") 4 specimens per blank

Glue spread 7.5 cc. + 7.5 cc. distributed on both scarfed surfaces 3.5" x 5", corresponding to 0.4 cc. per square inch; TA (open = 10 minutes at a room temperature of 74° F. ± 2.5°; curing time by high frequency between parallel electrodes 2 cycles of 3 minutes each, changing poles between intervals; pressure 150 psi; equilibrium moisture content = 11%. Cooled for about three hours under pressure in a cantilever-type press, and specimens reconditioned to e.m.c. of 11%.

Types of failure:

Compression: 100% in wood, away from glue line.
Tension and toughness: In glue line, slight fiber percentage.

Computation: Total load P divided by measured area of glue line as in Table 1. Number of specimens: Each type of surface preparation, lw specimens, except for sanding, 6 specimens; each alignment (springwood to springwood, etc.) 4 specimens each, out of a total 12; other gluing and testing conditions similar to those of Table 1.

stance," F_s in summerwood is 2.5 times as large as F_{sp} in springwood, and porosity, P_{sp}, in springwood is 1.3 times as large as P_s in summerwood.

$F_s = 0.33$ for $r_s = 0.50$ and
$F_{sp} = 0.13$ for $r_{sp} = 0.20$ from which: 2.5 F_{sp} F_s and
$P_s = 0.67$ for $r_s = 0.50$
$P_{sp} = 0.87$ for $r_{sp} = 0.20$
1.3 P_s P_{sp}

3. In springwood-summerwood joints, the strength is determined by the springwood, as would be expected, since this is the weakest link in the joint.

Contact Factor and Its Influence on Joint Strength

In the context of this investigation, for the problem of end-wood gluing, the "contact factor" seems to be significant. This is not necessarily the case for edge-glued or industrially used finger or scarf joints (refer back to "areas of contact"). A contact factor can be distinguished on a macroscopic scale and on a microscopic scale.[8]

Not knowing the relationship between surface roughness and contact area for wood, we could by analogy with other elasto-plastic materials, assume linear, direct proportional function. Ideally, smooth surfaces would give absolute, or 100 per cent, contact; surfaces formed as pyramids, for instance, 0 per cent contact. From the results presented in Tables 1 and 2, it can be seen that the macroscopic index of surface trueness does affect joint strength. In both cases, in scarfed and butt-end joints, the highest indices (between 3.2 and 4.03), and with direct proportionality assumed between surface roughness and contact area, lowest contact area of the mating surfaces, give the weakest joints.

It was expected that the alignment factor for springwood and summerwood would be significant. However, results of microscale joint tensile strength studies, and de Riberolles' work (7) conclusively prove that, with the glue used, joint strength is independent of alignment and positioning of the growth rings. Springwood aligned to springwood, summerwood to summerwood, "mixed" joints, and "crossed" growth rings gave joints of about the same strength.[9]

On a microscopic scale, with the center-line average (C.L.A. index) as a measure, the flat-ground sawn surface is roughest—C.L.A. > 200 — and gives the strongest joint. This can probably be explained on the basis of the influence of anatomic structure on joint strength.

When two wood surfaces with respective "fill-in" F_1 and F_2 are to be glued together, the following modes of contact between glue and wood can be visualized in a microscopically small area of these surfaces: 1) contact with cut wood only in one surface; 2) contact with cut wood on the other surface; 3) contact with cut wood on both surfaces; and 4) no contact at all with cut wood substance.

Probabilities for the different modes will be:

$$S_1 = F_1 (1 - F_2)$$
$$S_2 = F_2 (1 - F_1)$$
$$S_3 = F_1 F_2$$
$$S_4 = S_1 + S_2 + S_3 + S_4$$

Resultant stresses in the joint surface can be broken down into corresponding components:

$$= \sigma_1 F_1(1 - F_2) + \sigma_2 F_2(1 - F_1) + \sigma_3 F_1 F_2 + \sigma_4(1 - F_2) \text{ and}$$
$$= \tau_1 F_1(1 - F_2) + \tau_2 F_2(1 - F_1) + \tau_3 F_1 F_2 + \tau_4(1 - F_1)(1 - F_2)$$

The term $\sigma_3 F_1 F_2$ will probably be *dominant* for the strength of the joint for most types of stresses. Clear experimental evidence that this dominance is actually the case is thus far lacking. Further research is planned, especially for end-wood joints, with respect to contact of the glue with cut and uncut surfaces.

When cross sections of wood are glued, it is desirable to obtain a good bond between contacting cell walls; the strength of these bonds should be of approximately the same order of magnitude as the cohesion of the cell walls alone. This cannot give "100 per cent glue joint", however, because the bearing area, F_1F_2, is less than the bearing area of the cell walls in the surfaces joined. To increase joint strength, we shall have to rely on contributions from the other terms, that is, on the ability of the adhesive to transmit forces between surfaces *that are not in contact*. We can glue springwood to springwood, and it should be feasible to glue summerwood to summerwood, to the full strength of Douglas-fir or redwood. The real problem, however, seems to be to, eliminate the reduction in strength caused by the contact of springwood with summerwood, and the reduction in strength between other areas of the surfaces not in direct contact.

Discussion

The mode of preparation of Douglas-fir surfaces to be glued had only moderate influence on joint strength in the butt-end and 45 degree-angle scarfed joints. A flat- and hollow-ground saw, machine- and hand-planer, and sanding were tested. The flat-ground saw gave the roughest joints as measured by the center-line average (C. L. A. index). This surface also gave the strongest joints. The hollow-ground saw, measured by a macroscopic method of surface trueness, gave the greatest deviations from the geometric ideal plane, and also the weakest joints.

An explanation is that an uneven, fuzzy surface of the glue joint results in better distribution of localized stresses, and that the loosened wood fibers give better reinforcement to the glue line. Further studies will be necessary to clarify this point.

Compression shear strength was tested by specially developed specimens 2 by 2 by 8 inches. The load was applied parallel to the grain, 45 degrees oblique to the glue joint. In almost all cases the wood failed, under these testing conditions, away from the glue joint. This indicates that the particular glue used is rather strong in compression, but not in tension, which is probably true of all commercial wood glues at present.

The micro-tensile strength tests show that springwood in Douglas-fir can be glued satisfactorily even in butt-end jointed specimens. Summerwood joints barely reach the strength of springwood joints. Mixed joints reach about the strength of a pure springwood joint.

The explanation for this could be either that adhesion of the glue to summerwood is insufficient in short scarfed or butt-end joints, however excellent it might be in longitudinal joints, or that cohesion of the glue is insufficient to transmit stresses between surfaces of summerwood, or both.

The significance of the contact factor concept on a macroscopic scale, when contacting surfaces are of different orders of roughness, and on a microscopic scale when fill-in is either identical or different in both mating surfaces, requires further investigation.

Further basic and applied research will be directed toward selection or development of an adhesive of in-

[8] The mathematical assessment, that is, the derivation of the real area of contact from surface texture measurements, is difficult. It would be necessary to relate somehow the yield pressure of wood to some representative measure of the elastic limit of deformation of wood, that is $p_{max} = cY$, where c is a constant depending on wood properties, shape, and dimensions of surface irregularities, and Y is some measure of elastic limit of the wood. The problem is similar to that of the contact factor in rubbing solids, such as bearings, etc., and it will require special studies, particularly microscopic investigations, to show the extent of deformation due to surface preparation (machining) and that due to gluing pressure. See Perthen, J., Prüfen und Messen der Oberflächengestalt, München, 1949, and Bowden and Tabor, The Friction and Lubrication of Solids, Oxford, 1954, and reference (4, 5).

[9] This might not necessarily be the case if other glues with gap-filling or higher strength properties are used.

proved physical properties, and development of advanced gluing procedures on the basis of the preceding results.

Summary

The influence of surface texture on the strength of glue joints, as produced by anatomic structure and machining variables, has been investigated on the basis of mathematical model concepts originally developed at the Swedish Forest Products Research Laboratory in Stockholm.

For edge-glued joints of Scotch pine *(Pinus sylvestris)* from Sweden, the relationship between porosity, surface texture (roughness) determined from photomicrographs of tangential sections, and shear strength of tangentially glued specimens was determined (2). The tests included glue bonds of springwood and summerwood with an average roughness factor $R_s = 1.15$ and $R_{sp} = 1.85$.

The investigation proved that the strength of these joints increases with the roughness of the surface until a point is reached at which the simultaneously decreasing strength and increasing porosity cause the wood to break. Beyond this point, an increase in roughness diminishes the shear strength of the joint.

This behavior of wood is in agreement with the behavior of nonporous materials such as metals, in which the surface-roughness — shear-strength curve shows a definite maximum (Suchsland, K. 1957).

The use of an electronic stylus tracer-type recording instrument with an automatic integrating device made possible a more refined and efficient technique for registration, mathematical assessment, and evaluation of surface textures in wood. The sensitivity of the instrument permits the resolution of such anatomic structural details as cell dimensions, porosity, cell-wall fractions, fill-in, and density, as well as springwood and summerwood distribution within growth rings.

In short-scarfed joints (ratio 1:1) of Douglas-fir, produced in matched samples under rigid dimensional and surface control by high-frequency gluing with a resorcinol glue, the roughest surfaces (flat-ground saw) gave the strongest joints when tested for tension and impact bending. The center line average (C. L. A. index) was used as a criterion. On a macroscopic scale, the surface trueness index was highest for the surfaces prepared by a hollow-ground saw, but these resulted in the poorest joints.

In this Laboratory, de Riberolles, using the same technique for butt-end jointed samples, achieved essentially the same results. In addition, he found that alignment and positioning of growth rings and direction of cutting have no influence on joint strength. This again has been confirmed by tensile tests with microscopic specimens.

The concept of contact area and contact factor is discussed on the basis of wood as an elasto-plastic body, and demonstrated in photomicrographs of glued joints.

The tensile strength of springwood-springwood, summerwood-summerwood, and mixed joints was related to density, porosity, and cell-wall fraction, and the determination of their contribution to total joint strength was based on the theory advanced by Ylinen in Finland.

In a particular sample of Douglas-fir, pure springwood joints reached the strength of solid springwood, but in the summerwood joints only about 15 per cent of the strength of solid summerwood was obtained. In "mixed" joints, the strength was determined by the weaker springwood. Possible explanations are that adhesion of the glue is insufficient in summerwood; cohesion (strength) of glue is insufficient to transmit stresses between surfaces; or both. Springwood can be glued to springwood satisfactorily, and it should be possible to glue summerwood to summerwood. *The real problem seems to be the elimination of the reduction in strength caused by the contact of springwood with summerwood.*

This could probably be achieved by the development of adhesives and procedures in which the resulting joint is capable of transmitting forces between surfaces that are not in contact. This will be the objective of further research.

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Can Research Help You ?

If scientific research is used properly, the rewards can be large and gratifying, if used improperly, results will be costly and discouraging, W. M. Murray, Jr., Director, of the Southern Research Institute pointed out in a recent speech in South Carolina. He outlined seven conditions for research to help a business enterprise.

1) Your need or problem must be one that can be solved by scientific research.

2) Access to competent research services must be available, either through a firm's own facilities, consultants, testing laboratories, research institutes, or college laboratories.

3) Sufficient time and money must be made available to complete the research required.

4) Someone in your firm must control the research program and see that research efforts are coordinated with company objectives and abilities.

5) Time and money for adequate development and testing are necessary for new products that may result from research.

6) Adequate capital must be provided for new equipment and possibly a plant necessary to get your new product into production.

7) A high degree of entrepreneurship should be applied to this new development, so your product will become known to consumers.

If the proper procedure is followed, the small business or individual can have the same kind of benefits from research as does the industrial giant.

Moisture Movement in Beech

BELOW THE FIBER-SATURATION POINT[1]

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Associate Professor, Department of Wood Products Engineering,
State University College of Forestry at Syracuse University

Two moisture-movement mechanisms were found to operate below the fiber-saturation point in beech. Vapor movement was dominant in the radial direction because of the high temperature effect, while bound-water movement was more important in the tangential direction because of the relatively low temperature effect.

DESPITE THE FACT that millions of board feet of wood are seasoned each year, the mechanism by which the water moves through the wood during the seasoning process is not completely understood. Improvement in the methods for drying wood require a better understanding of this mechanism and how it is affected by various controllable factors.

It is the purpose of this paper to discuss the mechanism of moisture movement in wood in general, with particular emphasis on movement through American beech *(Fagus grandifolia* Ehrh.) heartwood at moisture contents below the fiber-saturation point. The discussion is based on experimental determinations of rates of moisture movement through beech in the radial and tangential directions as a function of wood moisture content and temperature.

To discuss the mechanism of moisture movement through wood quantitatively in terms of the variables that affect the mechanism, it is necessary to define a factor that gives a measure of the rate of moisture movement under given conditions. This factor for steady-state conditions is analogous to the coefficient of heat conductivity and is defined as follows:

$$K_m = -(1/A)\,(dq/dt)/(dM/dx) \quad \text{----------(1)}$$

where $(1/A)\,(dq/dt)$ is the steady-state flux or rate of flow of moisture q (grams) per unit time t (seconds) per unit area A (square centimeters), and dM/dx is the gradient of moisture content M (per cent of oven-dry weight) per unit distance x (centimeters) in the direction of the gradient. The units of the moisture conductivity coefficient K_m in this case therefore are grams centimeter^{-1} second^{-1} per cent^{-1}. It applies, of course, only for unidirectional movement along the x-axis.

The use of equation 1 for describing the rate of moisture movement through wood is valid only for the case of steady-state movement. When the moisture content of the wood changes with time, as it does during the drying process, another coefficient is required. This coefficient, in analogy to the coefficient of heat diffusion, is called the moisture diffusion coefficient (18). It is related to the conductivity coefficient by a factor that is proportional to the specific gravity of the wood. Thus

$$D = (100/G)K_m \quad \text{----------(2)},$$

where G is defined as the oven-dry weight (grams) of the wood, divided by the volume (cubic centimeters) taken at the moisture content M. The diffusion coefficient D therefore has units of square centimeters per second. The term G has units of density (grams per cubic centimeter) but is numerically equal to the specific gravity of the wood as defined in the American wood-using industry.

The importance of the moisture diffusion coefficient D in determining the rate of drying of wood is evident from its appearance in the unsteady-state moisture diffusion equation in one dimension,

$$\partial M/\partial t = \partial(D\partial M/\partial x)/\partial x \quad \text{---(3)},$$

which describes the time rate of moisture content change $\partial M/\partial t$ at any point in a drying board as a function of the rate of change with distance x of the product of D and the moisture gradient $\partial M/\partial x$. It is evident from equation 3 that the rate of drying $\partial M/\partial t$ is directly proportional to the moisture diffusion coefficient D, and that this factor is more important than the conductivity K_m alone in determining drying time. Furthermore, the coefficient D can be obtained directly from unsteady-state drying experiments by the method described in this paper.

Experimental Measurement of the Moisture Diffusion Coefficient

Material: The material used in this experiment was obtained from three beech logs, each cut from a different tree that grew near Syracuse, New York. The log diameters and lengths were about 17 and 80 inches, respectively. Each log was sawed within two days after it was felled to obtain two flat-sawn and two quarter-sawn boards of one-inch surfaced thickness. The flat-sawn boards were trimmed to five-inch widths and the quarter-sawn to four-inch widths. All the boards were resawn into 14-inch lengths after first removing obvious defects such as knots. The individual lengths were numbered with respect to original location in the boards, and these locations were randomized with respect to the subsequent temperature at which each sample was dried during the determination of the moisture diffusion coefficient.

Six quarter-sawn and six flat-sawn lengths were used from each of the three logs for a total of 36 samples. One quarter-sawn and one flat-sawn sample from each log was tested at each of the six temperatures used. Prior to use, each sample was stored in a polyethylene bag at a temperature of 0° F.

Drying Procedure and Results: The 14-inch samples were removed individually from the deep-freeze, and were coated on the ends and edges with two heavy coats of a commercial end-sealer, which a preliminary experiment showed was effective in preventing significant loss of moisture from the ends and edges of similar samples.

[1] A contributed paper (May, 1958) based on a dissertation presented in partial fulfillment of the PhD degree at Yale University.

The Author: Christian Skaar holds BS and MS degrees from State University College of Forestry at Syracuse, and a PhD from the Yale University Graduate School.

They were allowed to dry slowly at room temperature in a conditioning room, with the drying surfaces exposed to gradually decreasing humidities until the generel level of moisture content was below fiber saturation, and reasonably steep moisture gradients were established. At this point, each sample was resawn into paired 7-inch lengths, which were then recoated with the end-sealer to give a total of at least 3 layers of the sealer on all edges and ends.

For the actual drying experiment, both the paired specimens were subjected to drying conditions in the drying chamber[2] to permit them to attain temperature equilibrium with the chamber. After this initial drying period, one of each pair of matched specimens was withdrawn from the chamber, wrapped, and cooled quickly with "dry-ice" (solid carbon dioxide) to prevent further change in moisture distribution in the sample.

After they were cooled, three wafers, each about ¼ inch thick, were cut from the sample. These were spaced one inch apart center-to-center as shown in Fig. 1, where the sample marked t_1 represents the sample removed from the drying chamber after the initial drying period, designated as the time t_1. The three wafers from each t_1 sample were immediately wrapped in "Saran" (vinylidene chloride) film and stored at 0° F. until the sectioning process. The actual sectioning was accomplished by means of a sharp microtome knife. The wafers, which were 4 or 5 inches wide, were first trimmed to a 2-inch width, after which they were sectioned rapidly into 10 strips with the microtome knife. A wooden mallet was used to strike the knife. The strips were individually wrapped in "Saran" film to prevent moisture loss prior to weighing.

The second half of each matched pair was removed from the drying chamber at the time t_2, a convenient interval after time t_1. Three wafers, corresponding in position to the three cut from the t_1 samples, were cut from each of the t_2 samples and sectioned as before.

The moisture contents of the individual strips, which weighed about 500 milligrams each, were calculated gravimetrically by means of a microgram rapid-weighing projection balance, which permitted weighings to within 0.1 milligram in less than 20 seconds. Thus the moisture contents in the strips could be calculated to within 0.1 per cent with negligible loss of moisture during the weighing operations.

[2] The drying chamber consisted of a small cabinet, about 2 by 2 by 3 feet in size, equipped with temperature control to within ± ½ degree C and with a circulating fan. It was not necessary to control humidity accurately in the technique used for this experiment, since moisture gradients were obtained by actually sectioning the drying samples.

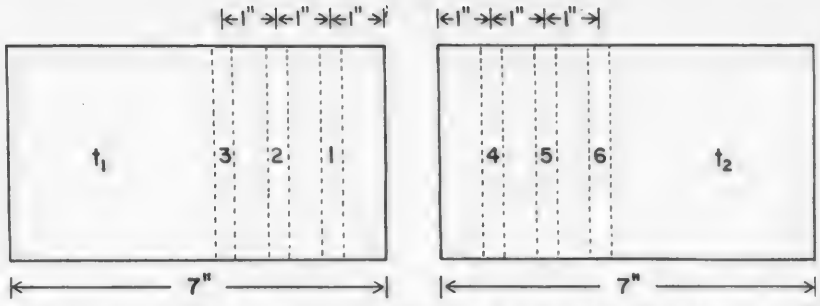

Fig. 1.—Typical pair of test samples, showing the six locations from which the test wafers were cut. Wafers 1, 2, and 3 were cut from the sample removed at the time t_1, and wafers 4, 5, and 6 were cut from the sample removed at the later time t_2.

The mean moisture content distribution in each wafer was plotted after pooling the corresponding five mirror-image pairs of strips in the wafer, and after adjusting for the effect of varying strip thicknesses. For each pair of test samples there were 6 moisture distribution curves available, 3 for the time t_1 and 3 for the time t_2. Therefore, 3 pairs of curves were plotted for each pair of test samples, each containing a t_1 and t_2 curve. Fig. 2 shows a typical pair of moisture distribution curves. The broken line intermediate between the t_1 and t_2 curves represents the mean moisture distribution during the time interval t_2-t_1.

From the curves of moisture distribution at two successive drying times t_1 and t_2, the moisture diffusion coefficient was calculated for even integer values of moisture content over a range of moisture contents by means of a modification of the method of Egner (∂). Thus, referring to Fig. 2, the diffusion coefficient D for the moisture content M' was obtained by substitution in the equation

$$D = \left\{ \left(\Delta \int_0^{x'} M\,dx \right) / (t_2 - t_1) \right\} \left\{ 1/(\partial M'/\partial x) \right\} \text{----------} (4),$$

where the term $\Delta \int_0^{x'} M\,dx$ is represented by the shaded area whose limits O and x', and the two moisture distribution curves t_1 and t_2. The gradient $\partial M'/\partial x$, taken at the point x' is the slope of the broken curve that represents the mean moisture distribution during the time interval $t_2 - t_1$.

Since time $t_2 - t_1$ was calculated in seconds and x was a fraction of the half thickness a, which was measured in centimeters, the units of the diffusion coefficient D were calculated in square centimeters per second.

Analysis of the data showed that the transformation of the diffusion coefficient to its logarithm gave an essentially linear relationship with moisture content, so all the results were transformed into the logarithm of D. Three replicated values of the variate log D were available for each test sample over the moisture range covered. The mean of these 3 values was calculated in each case, and these mean values were plotted as a function of moisture content for each of the 36 samples tested. The mean value and slope of each of these curves was calculated by the method of least squares.

Statistical analysis of the slopes of the linear curves of log D against moisture content demonstrated that there was a significant effect of moisture content on the radial diffusion coefficient, but none for the tangential value. The analysis also showed that there was no significant effect of temperature on these slopes for either radial or tangential movement.

The analysis of the effect of temperature showed a linear relation between the logarithm of the mean dif-

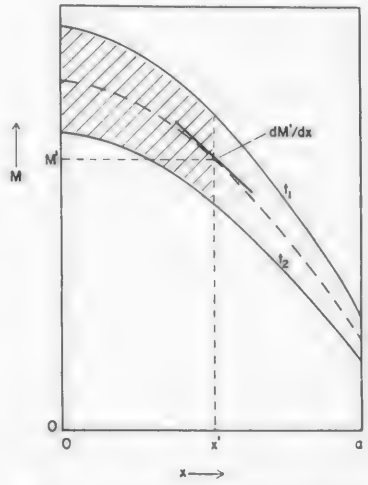

Fig. 2.—Typical moisture-distribution curves for the drying times t_1 and t_2. The broken curve represents the mean moisture distribution during the drying interval t_2–t_1, and the slope of this curve dM'/dx at the point x' is the mean moisture gradient at the moisture content M'. The shaded area represents the term $\Delta \int_0^{x'} M\,dx$.

fusion coefficient and the reciprocal of absolute temperature for both radial and tangential movement. The effect was more pronounced for radial than for tangential movement, however. On the basis of these analyses, regression equations were calculated relating the radial and tangential diffusion coefficients to wood moisture content and temperature.

The regression equation for tangential movement was

$$\log D = -1.98488 - 1.2561\,(1000/T) \quad \text{----------(5)},$$

and for radial movement

$$\log D = 0.36795 - 2.0608\,(1000/T) + 0.03157M \quad \text{----------(6)},$$

where D is in square centimeters per second, T is in degrees Kelvin, and M is in per cent moisture content. Figs. 3 and 4 show the graphical representation of equations 5 and 6.

The Mechanism of Moisture Movement in Wood

The results obtained in this study can best be interpreted by consideration of the mechanism of moisture migration in wood and the effect of the variables of moisture content and temperature on these mechanisms. A qualitative discussion of the principles of moisture migration is given, followed by application of these principles to the interpretation of the results.

General Mechanisms: It is generally considered that water migrates through wood by at least three different mechanisms. These are:

1. Movement of capillary water in the cell cavities above the fiber-saturation point due to capillary-pressure differences.
2. Movement of water vapor through the cell cavities and pit cavities, above and below the fiber-saturation point, due to vapor-pressure differences.
3. Movement of hygroscopically bound water through the cell walls of wood below the fiber-saturation point due to moisture content differences.

The movement of water through wood at moisture contents above the fiber-saturation point is not considered in detail in this paper. The complex mechanism at these high moisture contents involves capillary-pressure differences as well as the corresponding vapor-pressure differences. Both these pressure differences are caused by variations in the diameters of the air-water menisci in the cell cavities of the wood. This mechanism has been discussed by Hawley (7)[3], Kroll (10), and Kübler (12) as well as others.

[3] Numbers in parentheses refer to the Literature Cited.

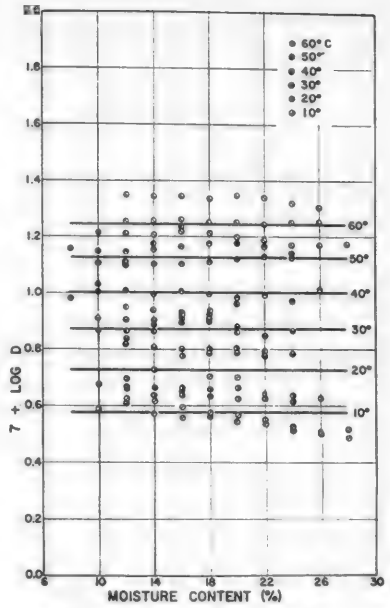

Fig. 3.—Family of curves for tangential moisture movement showing a graphical representation of equation 5, in which the logarithm of the diffusion coefficient D, where D is in square centimeters per second, is shown as a non-varying function of the wood moisture content over the range of temperatures covered in this experiment.

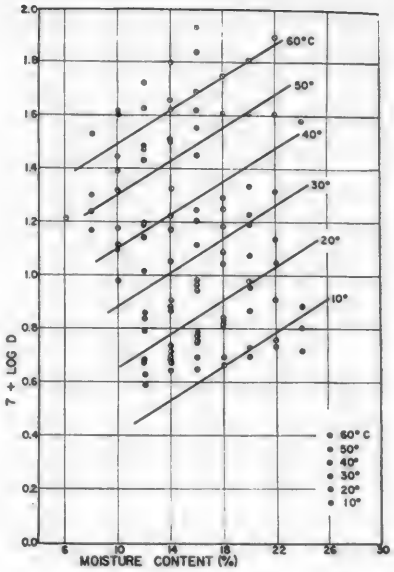

Fig. 4.—Family of curves for radial moisture movement, showing a graphical representation of equation 6. The logarithm of the diffusion coefficient D, where D is in square centimeters per second, is shown as a function of wood moisture content over the range of moisture contents and temperatures covered in this experiment.

The effect of capillary pressures and associated vapor pressures on the rates of moisture movement above the fiber-saturation point is extremely sensitive to small variations in the structure of wood. Consequently, the moisture diffusion coefficient at these high moisture contents is also greatly influenced by small structural differences in the wood. In general, however, it has been found that the moisture-diffusion coefficient is lower at moisture contents well above the fiber-saturation point than in the hygroscopic range, and that a higher moisture gradient is therefore required for water to move at a given rate (2, 7, 20).

Since this paper is primarily concerned with the mechanism of moisture movement in beech below the fiber-saturation point, only two mechanisms are discussed in detail. These are the water-vapor mechanism and the bound-water mechanism.

Mechanism of Water-Vapor Movement in Wood: It is important to distinguish between the movement of water vapor under conditions of hydrodynamic flow and the movement under conditions of true diffusion. Pfalzner (16) has differentiated between the two mechanisms on the basis that, in the case of hydrodynamic flow, the water vapor migrates from a region of high *total* vapor pressure to one of low *total* pressure, whereas in true diffusion the *total* vapor pressure of all gases is constant, and the water vapor moves from a region of high *partial* water vapor pressure to one of low *partial* pressure.

The hydrodynamic flow applies when water vapor is the only gas present, whereas true diffusion applies when other gases are also present. In the case of wood, it must be presumed that additional gases are present in the cell cavities in addition to water vapor at temperatures below the boiling point of water. Since the temperature range covered in this study was between 10° and 60° C. it is presumed that the water-vapor movement was a true diffusion process.

The diffusion of water vapor through the pores of wood may obey different laws than those governing the diffusion of water vapor in still air, even if the driving force in both cases is a partial vapor-pressure gradient. Babbitt (1) has distinguished 4 types of vapor diffusion depending upon the size of the pores compared with the mean free path[4] of the vapor molecules. The mean free path of water-vapor molecules in the temperature range from 10° to 60° C. is in the order of 0.1 micron (19). It is evident therefore that, for vapor movement through the cell lumens of beech, whose diameters vary from 1 or 2 microns for the dense fibers up to almost 100 microns for the vessels (3), the mean free path is much

[4] The mean free path of the molecules in a vapor, according to the kinetic theory of gases (4), is the mean distance a molecule travels between collisions with adjacent molecules. It is calculated from the Maxwell distribution law for velocity distributions of molecules in a gas.

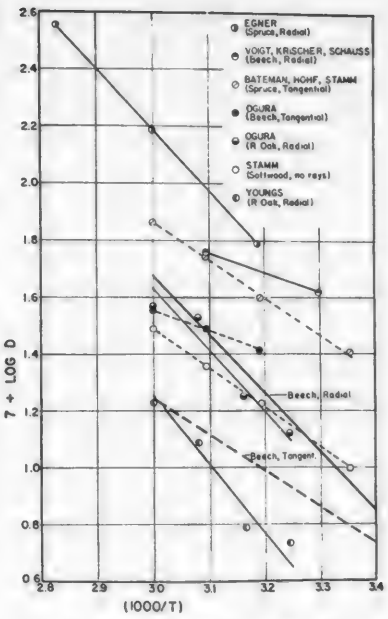

Fig. 5.—Curves showing the effect of temperature on the diffusion coefficients for various woods in the radial and tangential directions. The logarithm of the diffusion coefficient (7 + *log D*) where *D* is in square centimeters per second, is plotted as a function of the reciprocal of absolute temperature in each case. The solid lines are those for radial movement and the broken lines are those for tangential movement. The legend showing the sources for the points through which the lines were drawn are given in the figure.

lower than the pore diameters, and the simple laws that govern the diffusion of gases in still air apply.

According to Stamm (20), water-vapor movement also takes place through the permanent pit-membrane pores that have been shown to exist in softwoods. These have been calculated to be in the order of 0.1 micron, according to Hawley (7), which is approximately the same as the mean free path of the water-vapor molecules. In this case, the laws governing vapor movement through the cell lumens do not apply, since the collisions of water-vapor molecules with the pore walls occur with approximately the same frequency as collisions with other molecules. Pit-membrane pores have not been demonstrated in hardwoods. Liese (13) concluded from electron micrograph studies that there are no pores in the intervessel pit membranes of the European species of *Fagus, Betula, Populus* and *Salix*.

Mechanism of Bound-Water Movement in Wood: Several mechanisms have been proposed to explain the movement of bound water through the cell wall of wood. Each of these mechanisms is based on some assumption with regard to the manner in which water is held in the cell wall.

The classical mechanism for explaining the hygroscopic isotherm for wood is the combination of the monolayer Langmuir adsorption isotherm at low wood moisture contents with multilayer or capillary adsorption in the higher range of moisture contents.

Stamm (20) assumes that there is little moisture movement through the cell wall at moisture contents where the Langmuir monomolecular adsorption occurs, that is, below about 6 per cent. He has recently (21) confirmed this assumption for dry cellophane by measuring the moisture diffusion coefficient of cellophane as a function of moisture content.

Hermans (8) agrees in essence with Stamm, and has pointed out that bound-water diffusion through cellulose must be extremely slow at these low moisture contents because of the high affinity of water for dry cellulose.

At moisture contents above about 6 per cent, Stamm (20) considers that bound-water movement takes place as a diffusion process in which the capillary or polymolecularly held water diffuses through a system of monomolecularly held water.

Kroll (11) has assumed that bound-water movement above about 10 per cent moisture content is by capillary forces. In agreement with Stamm, Kroll concludes that the bound-water diffusion in the cell wall increases markedly with increasing moisture content.

Babbitt (1) has derived relationships for the diffusion of adsorbed molecules through a solid for the case where the adsorption obeys the Langmuir isotherm, and also for the case where the Brunauer, Emmett, Teller equation for polymolecular adsorption applies. In both cases, the diffusion coefficient increases with increasing adsorption. In the case of wood, where both these equations have been applied to explain the adsorption of water, the results imply that the bound-water diffusion rate increases with increasing moisture content.

Regardless of the mechanism assumed for moisture movement in the cell wall of wood, the conclusion is apparent that the bound-water diffusion coefficient increases with increasing wood moisture content.

Combined Vapor and Bound-Water Movement in Beech: The mechanism of moisture movement through wood below the fiber-saturation point is a combination of vapor and bound-water movement. The results reported in this paper for beech indicate that the relative importance of the two mechanisms undoubtedly is different for tangential and radial movement. This conclusion follows from the fact that both temperature and moisture content have different effects on the moisture-diffusion coefficients in the two structural directions. The effect of temperature is discussed first, followed by consideration of the effect of wood moisture content.

If moisture movement through wood is controlled predominantly by the vapor mechanism, the effect of temperature on the moisture-diffusion coefficient should be similar to its effect on the vapor pressure of wood at constant moisture content. This is anticipated because the rate of vapor movement is proportional to the vapor-pressure difference, while the total moisture movement is assumed to be proportional to the moisture-content difference in calculating the moisture-diffusion coefficient.

The vapor pressure-temperature relation for beech is not available, but Stamm (22) has given data for Sitka spruce in which the logarithm of vapor pressure is essentially linearly related to the reciprocal of absolute temperature at constant moisture content. The relation varies slightly with moisture content, but over the range of moisture contents of interest in this study (10 per cent to fiber-saturation point), it can be described approximately by the equation,

$$\log h = 3.95 - 2.25(1000/T) \quad (7),$$

where h is the vapor pressure in millimeters of mercury and T is absolute temperature in degrees Kelvin.

It is apparent by comparing equation 7 with equation 5 that the moisture-diffusion coefficient for tangential movement is not nearly so sensitive to temperature as would be expected if the movement were completely vapor-diffusion controlled. The coefficient (1.2561) for the temperature effect for tangential movement is only about half the value (2.25) that is anticipated for vapor movement. Comparison of the temperature coefficient (2.25) of equation 7 with the temperature coefficient (2.0608) for radial movement, on the other hand, indicates that the mechanism may be more nearly vapor-diffusion controlled since the coefficients are nearly the same.

The relative effect of temperature on the moisture-diffusion coefficient as measured or calculated by other workers is illustrated graphically by Fig. 5. The solid lines in the figure are for radial movement, and the broken lines are for tangential movement. In some cases, the data from which these curves were taken were given in the form of the moisture conductivity coefficient K_m. These were converted to the diffusion coefficient D by use of equation 2. The mean value of specific gravity for the particular wood was used in each case. For the cases where the measured diffusion coefficients

varied with moisture content, the values at 15 per cent moisture content were used.

In general, the results were in fair agreement with those obtained in this study, although there were some exceptions. The solid lines, representing radial movement, are of nearly the same slope, on the whole, as the results obtained for radial movement in this study. Similarly, the broken lines, representing tangential movement, show lower temperatures effects of the order of magnitude obtained in this study for tangential movement through beech.

The pronounced effect of temperature on the mechanism of vapor movement as described above is related to the high heat of adsorption of water vapor on wood (22). In addition to this strong temperature effect, another small effect should be mentioned. This is the slight increase in the rate of water vapor diffusion with increasing temperature for a given vapor-pressure gradient (20). This factor increases approximately as the square of the absolute temperature and, for the full temperature range from 10° to 60° C., the rate of water-vapor diffusion increases by less than 40 per cent. This is almost negligible compared with an increase of well over 1000 per cent due to the effect of the vapor-pressure increase with temperature over the same range.

Bound-water movement at moisture contents in the range covered in this study is undoubtedly less temperature-dependent than is vapor movement. The water in the cell wall is relatively mobile if polymolecular layers of water are present, and the temperature effect should be much less than is associated with an activated diffusion[4]. It is probably of the order of magnitude of the temperature effect on the viscosity of water. On the basis of the data of Dorsey (5), the effect of temperature on the viscosity of water over the temperature range from 10° to 60° C. can be represented approximately by the equation

$$\log \eta = 0.86(1000/T) - 1.93 \quad \text{---------- (8)},$$

where η is the viscosity in millipoises and T is absolute temperature. It is apparent by inspection of equations 5 and 8 that the temperature effect for viscosity approximates the effect of temperature on the tangential moisture-diffusion coefficient.

[4] Activated diffusion may occur at extremely low moisture contents (less than 5 or 6 per cent) where high energy barriers must be overcome by individual molecules in jumping from one adsorption site to another. The energy of activation in this case should be of the same order of magnitude as the heat of adsorption of water on wood at these low moisture contents.

It is probable therefore that radial movement of moisture is more dependent on the vapor-diffusion mechanism than is the tangential movement. The reverse holds for bound-water movement. The reason for this may be explained in the number and nature of the cross-walls that must be traversed by moisture moving out of the wood during drying. For tangential movement, the rays have little effect and the number and thickness of cross-walls encountered by the migrating moisture limits the importance of vapor movement. For radial movement, the crosswalls are few in number and thin, because the rays, with their radially elongated, thin-walled cells, provide a relatively easy path for moisture movement.

The effect of wood moisture content was statistically insignificant for tangential movement. This agrees with the results of Ogura (15), who found that the tangential diffusion coefficient for Japanese beech *(Fagus sieboldi* Engl.) at 45° C. was essentially constant over the moisture-content range from 10 to 30 per cent. A similar effect was calculated by Stamm (20) for softwoods of the same specific gravity as beech over the moisture content range covered in this study. Since Stamm neglected the rays in his calculations, the results should be similar to those obtained for tangential movement.

The tangential diffusion coefficient for other woods has been shown to vary only slightly with moisture content. Schlüter and Fessel (17) determined that the tangential coefficient for European alder *(Alnus glutinosa* (L.) Gaertn.) decreased slightly with increasing moisture content at 75° C. between 5 and 18 per cent, while the tangential coefficient for Scotch pine increased slightly over the same moisture content range and temperature. Bateman, Hohf and Stamm (2) found an essential constancy for the tangential diffusion coefficient for Sitka spruce at 40° C. for air humidities corresponding to wood moisture contents between 5 and 20 per cent.

The marked increase with moisture content in the moisture-diffusion coefficient for radial movement in beech, as found in this study, is consistently verified for radial movement in many kinds of wood. Voigt, Krischer and Schauss (23) found an almost quantitatively identical moisture content effect for radial measurements on European beech. Kübler (12) reports that Ludwig, Sergowski, and Ogura independently obtained linear relationships of the logarithm of the radial diffusion coefficient and wood moisture content at 40° C. for European beech (Ludwig and Sergowski separately) and for Japanese beech (Ogura).

Martley (14) found an almost linear increase in the logarithm of the radial diffusion coefficient of Scotch pine with increasing moisture content at 40° C. Youngs (24) reported an increase in the radial diffusion coefficient with moisture content in the hygroscopic range for northern red oak heartwood at 37° C. and 60° C., and also for yellow poplar heartwood at 60° C. Egner's (6) results showed a several-fold increase in the radial-diffusion coefficient for spruce over the moisture content range from 3 to 25 per cent for temperatures of 40°, 60°, 80° and 100° C. Joy (9) established a similar effect for radial movement in ponderosa pine plywood over the relative-humidity range corresponding to 6 to 17 per cent wood moisture content. Although there were glue interfaces present in the plywood, they should not have had much effect on the relative effect of moisture content on the results.

It is difficult to explain the difference in the effect of wood moisture content on the radial and tangential diffusion coefficients although the rays probably are the cause. Dr. A. J. Stamm (personal correspondence) believes that the differences in boundary conditions during the experiments in the two structural directions may have caused this peculiar difference. Further investigation is necessary to clarify this point.

Conclusions

The mechanism of moisture movement through American beech below the fiber-saturation point takes place by a combination of vapor and bound-water movement. The effect of temperature is greater on the vapor mechanism than on the bound-water mechanism. The moisture-diffusion coefficient for radial movement in beech is more temperature-sensitive than for tangential movement, which indicates that vapor movement is relatively more important for radial than for tangential movement.

It is proposed that this difference is due to the rays, which occupy about 20 per cent of the volume of beech and provide a radial path for moisture movement in which relatively few cross-walls must be penetrated compared with tangential movement. The effect of moisture content on the radial moisture-diffusion coefficient is very pronounced—so much so that the logarithm of the diffusion coefficient increases linearly with moisture content. On the other hand, the tangential coefficient remains essentially constant with moisture content.

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Preservation of Particleboard

AND HARDBOARD WITH PENTACHLOROPHENOL[1]

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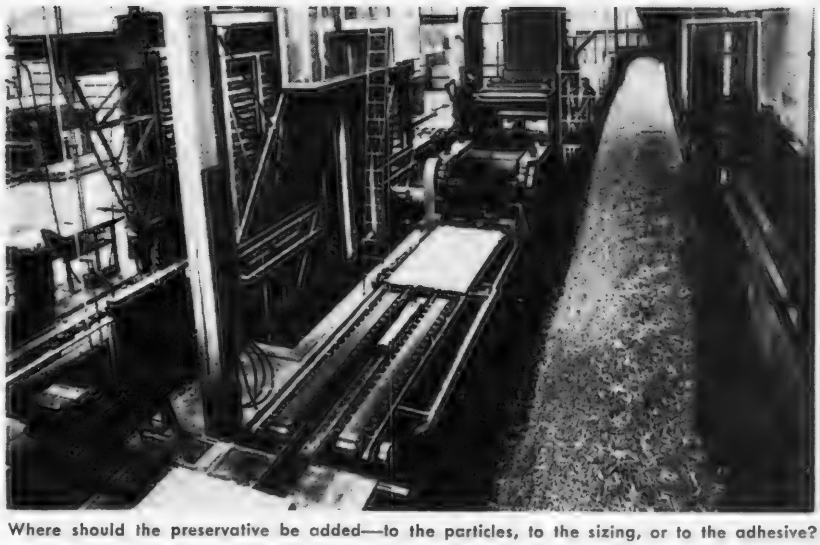
Penta can be incorporated during the manufacturing process at little cost other than for the preservative. Penta added in the glue looks good for commercial use, and does not affect strength.



Where should the preservative be added—to the particles, to the sizing, or to the adhesive?

IN PAST YEARS, the principal use for particleboard has been as a core stock used in furniture faced with wood veneer or plastic laminates. In the future it is expected that particleboard will also be used for other purposes where exposure conditions will be more severe. Examples of these other uses would be as floor underlayment and sub-flooring, wall paneling, ceiling covering, and interior mill work as in kitchen cabinets.

In 1956 in the United States, 1,100,000 houses were built. Fifty-five per cent of these homes had no basement and 43 per cent, had either a full or partial basement. Of homes without a basement, 16 per cent were built on a slab and 39 per cent were built over a crawl space. The average-size house built on a slab in 1956 was about 1,086 square feet. If one-half of all the homes built on a slab used particleboard as the underlayment for

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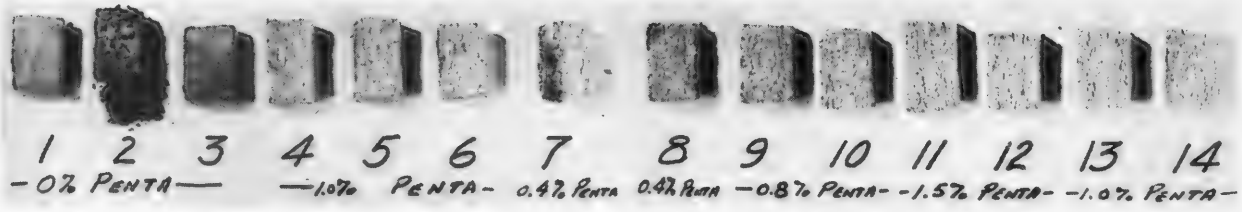

Fig. 1.—*Lenzites trabea* attack in a modified soil-block test on laboratory-produced particleboard.

tile or wood flooring, this would constitute a market of approximately 96,500,000 square feet of particleboard. There is obviously an even larger potential market for particleboard if used as underlayment in homes with crawl spaces.

The conditions of temperature and humidity in either underlayment or over crawl areas or slabs could certainly lead to decay or termite attack. Other parts of the home may be susceptible to attack by drywood termites in certain areas of the United States. Millwork used around kitchen sinks and washing areas would certainly be exposed to sufficient moisture for decay to be a problem.

The potential market for particleboard in tropical and subtropical climates is also large enough to warrant investigation. In these areas, storage and shipping conditions alone may be sufficient to allow molds and staining organisms to grow freely. The incidence of termite attack in the tropics is definitely greater than any encountered in the United States for almost all use conditions. The addition of preservatives to particleboard would thus allow its entry into new and expanded markets. It would improve the quality over existing products and place particleboard in a much improved competitive position.

Method of Preservative Addition

There are a number of possible methods for adding the preservative to the particleboard during the manufacturing operation. The preservative may be added to the wood particles or flakes before or after they are dried. It may also may be added directly to the adhesive and, depending upon the adhesive and the preservative, various changes may be required in either one or the other to produce a satisfactory product. There is also the possibility of incorporating the preservative in the sizing agent.

The preservative used for this study was pentachlorophenol and its water-soluble salt, sodium pentachlorophenate. This was a logical choice because of penta's proven service history in similar products, its commercial availability, and good handling and color characteristics.

The two most widely used adhesives in the particleboard industry are urea-formaldehyde and phenol-formaldehyde resins and, therefore, were the only ones employed in the work reported herein. There is no reason to believe, however, that application methods cannot be worked out for other adhesives.

In this work it was desired to preserve only the wood chips. The synthetic resins are considered resistant to decay, but do not impart this resistant quality to the wood.

Adding Preservative Directly to Wood Particles

The first method of preserving board attempted in the laboratory was by spraying the processed chips just prior to adding the adhesive. The chips were first dried to a moisture content slightly below that desired for proper resin addition to allow for the excess moisture added with the preservative. The wood chips were sprayed with the aqueous sodium pentachlorophenate.

Aside from the disadvantage that the spray mist proved slightly obnoxious to operators, the preserved board did not show the same physical strength as the control board. Therefore, a study was instigated in which plywood was used and the preservative applied by spraying the veneer surface next to the glue line. The plywood-shear test was used to evaluate strength. The bonding that occurs between the veneer layers in the plywood and the individual chips in the particleboard cannot be assumed to be the same. The results are comparable, however, and the plywood-shear test provided a convenient means of evaluation.

Sixty sheets of 1/16-inch yellow birch veneer were selected and dried. Thirty of these sheets were sprayed with a 10 per cent solution of sodium pentachlorophenate and 30 with an equivalent amount of distilled water. Each treatment group was manufactured into three-ply panels with the same spread of urea-formaldehyde resin. Four plywood-shear specimens were cut from each panel, and half of them were soaked in water at room temperature for 24 hours before testing. The results show that a definite loss in shear strength results from the preservative treatment described.

The question arises: What is the exact cause of the loss in strength? Several possible reasons exist, such as the contamination of the wood surface with the crystalline material or the effect of the sodium pentachlorophenate alkalinity on the adhesive.

To answer the question, another set of plywood tests was initiated. Veneer for subsequent gluing was treated in the following five ways:

Treatment I—veneer was sprayed with distilled water.

Treatment II—veneer was sprayed with 10 per cent solution of sodium pentachlorophenate.

Treatment III—veneer was sprayed with a solution of pentachlorophenol (10% concentration) and methanol.

Treatment IV—veneer was sprayed with a buffer solution adjusted to an equivalent pH of Treatment II.

Treatment V—wet veneer was sprayed with a 10 per cent solution of sodium pentachlorophenate and dried.

After each treatment, the veneer was reconditioned to a 10 per cent moisture content and manufactured into plywood panels with urea-formaldehyde resin. Five panels were made for each treatment group. Each panel was cut into four shear specimens and conditioned prior to testing.

The sodium pentachlorophenate and the pentachlorophenol-methanol treatments of the conditioned veneer resulted in somewhat lower strength, while the other treatments gave about the same average strength value. These findings indicate that the pH did not cause the loss in strength, but rather, surface contamination was the responsible factor. The maintenance of strength in the wet veneer sprayed with sodium pentachlorophenate (Treatment V) could be due to crystallization of the preservative below the wood surface during subsequent drying. In contrast with the specimens that showed loss in strength, the methanol or water would tend to evaporate and leave surface crystalline deposits of preservative, inasmuch as the specimens were sprayed with the preservative solution while in a relatively dry condition.

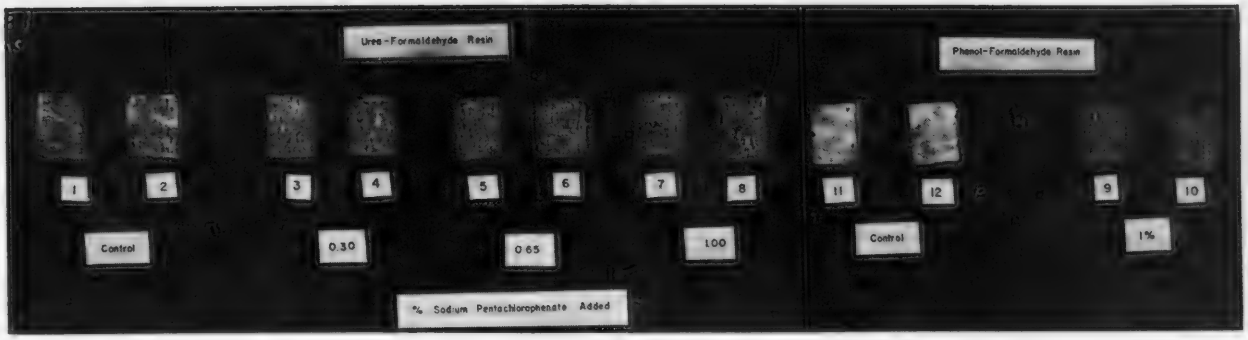

Fig. 2.—*Lenzites trabea* attack in a modified soil-block test on commercial particleboard.

It was concluded that, if the chips were to be sprayed directly with the preservative and the bond strength was to remain the same, the preservative should be added prior to drying the wood particles.

Adding the Preservative to the Sizing Agent

Pentachlorophenol is soluble in most of the wax sizing agents to a certain extent. With the majority, however, the solubility is not sufficient to permit adequate treatment with the small amount of sizing agent normally added to the particleboard. Sodium pentachlorophenate is likewise not soluble enough to give adequate protection with the amount of emulsion normally used.

Adding the Preservative to the Adhesive

Adhesives of the same general type may vary widely from manufacturer to manufacturer, and care must be exercised in adding supplementary materials such as preservatives. Little difficulty was experienced, however, in adding sodium pentachlorophenate directly to the urea-formaldehyde and phenol-formaldehyde resin. In one case, a urea-formaldehyde resin showed a tendency to cure prematurely, but this condition was alleviated by neutralizing the sodium pentachlorophenate with acid and suspending it in the adhesive.[2] With phenol-formaldehyde resins, a deepening of color may be noted after the sodium pentachlorophenate is added, but there seems to be no physical effect on the resin.

An alternate method of adding the preservative to the resin adhesive was worked out for pentachlorophenol. The required amount of pentachlorophenol for preservation was solubilized in an approximately equal amount of alcohol by weight. Isopropyl alcohol proved to be the most satisfactory because of its resin compatibility, penta solubility, and cost. This method was not investigated thoroughly, however, because of the increased flammability and added solvent cost.

The laboratory data indicated that the direct addition of the sodium pentachlorophenate to the resin with a slight excess of water would be a satisfactory procedure in the manufacture of particleboard. To establish this, however, it was necessary to carry out the procedure in a commercial plant. Other points also needed to be settled, such as the amount of preservative necessary for proper protection, the amount of preservative loss during subsequent hot-pressing operations, and the uniformity of preservative distribution throughout the board.

Commercial Plant Run

Several plant runs were successfully completed to produce board containing various combinations of sodium pentachlorophenate and urea-formaldehyde resin and one combination of sodium pentachlorophenate and phenol-formaldehyde resin. Controls bonded with each resin were also manufactured. Samples of the wood particles with the adhesive and preservative were taken before pressing for analysis of the preservative. Sections were cut from various portions of the finished board and analyzed to determine the preservative distribution. These analytical samples were also subjected to the soil-block test as described in ASTM D–1413–56T but modified by decreasing the incubation time and excluding the weathering cycle. Samples of the finished board were tested for modulus of rupture and per cent weight and thickness increase after a 24-hour soak.

The results obtained by analysis of the furnish and the finished board are reported in Table 1. In all cases, the per cent preservative was added on the basis of the dry wood weight. The analytical results must be adjusted to allow for the additional weight of adhesive, sizing agent, and water, which amounted to an estimated 12 per cent.

The analytical results show uniform distribution of the preservative throughout the different areas of the finished board. A comparison of the analysis of the wood chips plus adhesive and preservative with the analysis of the finished board shows little if any loss of the sodium pentachlorophenate during the hot-press operation.

The results of the soil-block testing are presented in Table 3. The range of weight loss on control specimens conditioned to equilibrium moisture content before and after exposure of six weeks to *Lenzites trabea* (Madison 617) was between 14 and 20 per cent. The attack on the phenol-formaldehyde bonded control specimens was equally as severe as that on the urea-formaldehyde bonded control specimens.

Fig. 3.—Exploratory particleboard tests with subterranean termites.

[2] Klauditz, W., and I. Stolley. 1954. Entwicklung und Herstellung pilz-und termitenfester Holzspanplatten. Holz als Roh-und Werkstoff. 12:185–189.

Table 1.—ANALYSIS RESULTS OF PRESERVED WOOD CHIPS AND FINISHED BOARD

Per cent technical grade sodium pentachlorophenate added[1]	Av. analyzed per cent technical grade sodium pentachlorophenate in furnish[2]	Calculated technical grade sodium pentachlorophenate based on dry weight of wood chips	Av. analyzed per cent technical grade sodium pentachlorophenate (2) in four board locations[3]			
			A	B	C	D
Urea-Bonded Board						
0.30	0.23	0.26	0.27	0.27	0.30	0.27
.65	.57	.66	.49	.49	.52	.53
1.00	.63[4]	.72[4]	.75	.77	.91	.76
Phenolic-Bonded Board						
1.00	----	----	.79	.67	.69	.85

[1]Per cent sodium pentachlorophenate added to resin, based on dry weight of wood chips.
[2]Analysis includes weight of adhesive, moisture, and sizing agent amounting to an estimated 12%. Average of two analyses.
[3]Location as follows: A—Top center edge of board, B—Top corner of board, C—Middle edge of board, D—Center of board.
[4]Low result may be due to inadequate mixing prior to sampling.

Table 2.—STRENGTH AND WATER ABSORPTION OF PRESERVED PARTICLEBOARD

Per cent technical grade sodium pentachlorophenate added[1]	Av. modulus of rupture[2]	After 24 hour soak[3]		Number of samples	Av. specific gravity[4]
		Av. per cent thickness swelling	Av. per cent weight increase		
Urea-Bonded Board					
Control	1435	6.3	10.2	4	0.61
.30	1747	4.7	9.2	4	.57
.65	1542	4.2	9.0	4	.62
1.00	1042	5.4	10.5	4	.52
Phenolic-Bonded Board					
Control	2146	4.1	9.4	4	.66
1.00	2339	4.1	8.2	4	.67

[1]Per cent sodium pentachlorophenate added to resin based on dry weight of wood chips.
[2]Over a 15-inch span and 3 inches of width.
[3]Water bath controlled to 70° F. with slight movement.
[4]Based on oven-dry weight and volume.

Table 3.—PARTICLEBOARD SOIL-BLOCK TEST

Per cent technical grade Sodium pentachlorophenate added[1]	Av. analyzed per cent technical grade sodium pentachlorophenate[2]	Calculated technical grade sodium pentachlorophenate based on dry weight of wood chips	Number of samples	Av. per cent weight loss[3]
Urea-Bonded Board				
Control	Control	Control	4	18
0.30	0.27	0.32	4	0[4]
.65	.52	.59	4	0
1.00	.76	.88	4	0
Phenolic-Bonded Board				
Control	Control	Control	5	17
1.00	.73	.84	4	0

[1]Per cent sodium pentachlorophenate added to resin based on dry weight of wood chips.
[2]Analysis includes weight of adhesive, moisture, and sizing agent, which amounted to an estimated 12%. Average of two analyses.
[3]After 6 weeks of exposure to Lenzites trabea (Madison 617).
[4]Visually appeared to have slight attack and some aerial growth on samples.

If weight losses were the only criterion of decay, the addition of as little as 0.30 per cent of sodium pentachlorophenate based on the dry weight of the wood would be sufficient to prevent decay under the conditions of this test. However, aerial growth was noted on the samples containing 0.30 per cent sodium pentachlorophenate and not on those containing 0.65 per cent. The threshold value, then, is probably between 0.30 and 0.65 per cent sodium pentachlorophenate added to the particleboard on the basis of the dry wood weight.

The results of the flexural tests are reported in Table 2. There appears to be little if any difference in the modulus of rupture caused by the addition of sodium pentachlorophenate.

The results of the water-absorption and thickness-swelling tests are reported in Table 2. The results show very little difference between treatment groups and no difference in water absorption or thickness swelling that could be attributed to the addition of the preservative.

Because of the interest in hardboard and its similarity to particleboard, soil-block tests were also conducted on this commercially produced material and reported in Table 4. The threshold was between 0.40 and 0.60 per cent technical grade sodium pentachlorophenate added on the basis of the dry weight of the wood. The method of adding the preservative will probably have to be adapted to suit each plant process.

Safety Considerations

The chemicals pentachlorophenol and sodium pentachlorophenate are recognized as materials that do offer potential health and handling hazards. In the past years, a considerable tonnage of both materials has been used in varied industrial applications with a minimum of difficulty, providing proper precautionary measures of handling were observed.

During the course of the experimental work, no health problems were encountered. During the application, however, practices of general good housekeeping were observed. It would follow, then, that under large-scale commercial production the operating personnel should observe good habits

Table 4.—HARDBOARD SOIL-BLOCK TEST

Per cent technical grade sodium pentachlorophenate added[1]	Av. analyzed per cent sodium pentachlorophenate	Number of samples	Av. per cent weight loss[2]
Control	Control	6	39
0.20	0.19	14	9
.40	.26	7	4
.60	.54	6	0
.80	.63	7	0
1.20	.94	6	0

[1]Per cent sodium pentachlorophenate added to resin based on the dry weight of wood fiber.
[2]After 8 weeks of exposure to Lenzites trabea (Madison 617).

of housekeeping and personal cleanliness. In addition, care should be taken to avoid direct skin and eye contact and breathing of the spray mist. Specific precautionary recommendations will be dependent upon the type of operations involved.

Cost of Preservation

If particleboard of 55 pounds per cubic foot is manufactured, approximately 12 per cent will be adhesive, water, and sizing agent. Therefore, approximately 49 pounds of dry wood chips will have to be preserved. If 0.60 per cent of sodium pentachlorophenate (based on the dry weight of the wood chips) is used at $0.25 per pound, the cost of preserving ½-inch board will be approximately 3/10 of a cent per square foot, or $3.00 a thousand square feet. The costs of preserving hardboard will be approximately the same, except that adjustments will be necessary for changed thickness and density.

Conclusion

In the near future, a sizeable market may develop for preserved particleboard and hardboard. The preservative may be added to the particleboard or hardboard during the manufacturing process at little additional cost over that of the preservative itself. The most satisfactory method of preserving particleboard bonded with either phenol-formaldehyde or urea-formaldehyde resin is by direct addition of sodium pentachlorophenate to the adhesive. The amount of sodium pentachlorophenate necessary to achieve protection in a modified soil-block test for both particleboard and hardboard is less than 0.65 per cent, based on the dry wood weight. With the addition of as much as 1.0 per cent sodium pentachlorophenate, added directly to the resin and based on the dry wood weight, no loss of flexural strength was noted in particleboard. Also, the addition of the sodium pentachlorophenate did not affect water-absorption or thickness-swelling properties over a 24-hour soaking period. Comparative strength and water-absorption properties have also been observed for preserved hardboard.

Fig. 1.—Two of the 12 test piles of 4/4-inch red oak lumber included in the study. The top left photo shows a pile typical of the six that were roofed; the right, a pile typical of the six that were not roofed. Roofs were made of corrugated steel on a wood frame. In all piles—both roofed and non-roofed—stickers were carefully aligned, and the lumber was supported 18 inches above the ground by a foundation of treated timbers.

Roof Your Lumber

AND INCREASE YOUR PROFITS[1]

W. P. Clark and T. M. Headlee
Forest Products Technologists, Carbondale Forest Research Center,
Central States Forest Experiment Station, Carbondale, Ill.

An air-seasoning study on red oak showed that lumber in roofed piles dries faster, more uniformly, and with less degrade. A $25 pile roof will pay for itself within five 90-day drying periods on No. 1 C&Btr.

Lumber air dried in a pile protected by a roof usually develops less degrade than that dried in piles without roofs. Much lumber is dried in non-roofed piles, however, because many operators feel that it costs too much to build, handle, and maintain pile roofs. This study, conducted at the Central States Forest Experiment Station Kaskaskia Experimental Forest in southern Illinois, shows the economic advantages of roofing red oak lumber during air drying.

Method of Study

Amount of degrade and rate of drying were measured during the air drying of 12 test piles of random width, 4/4-inch, 10- and 12-foot red oak lumber. All lumber was box piled, edge-to-edge, in piles about 12 feet long and 6 feet wide. Low piles (4 to 9 tiers high) were used because general observation has indicated that the beneficial effects of roofs are most apparent in the top few tiers of a pile.

Six of the piles were studied during a wet spring season; the other six during a dry summer season.[2] In both seasons there were two piles each of No. 1 Common and Better, No. 2 Common, and No. 3A Common lumber. One pile of each grade was roofed; the other was not roofed (Fig. 1). Four moisture-sample boards were prepared and placed in each pile.[2]

All moisture-sample boards were weighed periodically throughout the drying period to determine the rate of moisture loss. After approximately 100 days of air drying, the lumber was removed from the pile, regraded to determine loss of grade during drying, and inspected for occurrence and severity of bluestain, surface checking, and end splitting.

To study uniformity of drying within the piles, supplementary moisture content determinations were made on boards from the top three tiers and the next-to-the-bottom tier as each pile was taken down at the end of the drying period.

Examining the Results

Effect of Roof upon Lumber Degrade: Little degrade developed in the roofed piles during either season, but in both seasons most boards in the top three tiers of the non-roofed piles dropped one grade or more (Fig. 2). This drop in grade resulted in losses of value as high as $4.55 per 72 board-foot tier for non-roofed No. 1 Common and Better lumber (Table 1).[3] In all piles, severe surface checking was the major cause of degrade (Fig. 3), but checks were more numerous in non-roofed lumber than in roofed lumber.

Effect of Roof upon Rate of Drying and Distribution of Moisture within the Pile: In all instances, the moisture sample boards in the roofed piles dried to the fiber saturation point[4] several days sooner than those

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Thomas Headlee holds a BS in wood utilization from the University of West Virginia.

[1] Presented at Session XI, Wood Drying (Applied Research), FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

[2] All sample boards were prepared as recommended in "Methods of determining the moisture content of wood", U.S. Forest Prod. Lab. Report 1649 (1950).

[3] Lumber values per thousand board feet are based on June, 1957, Memphis Market Prices, adjusted to apply to southern Illinois mills, and are as follows: FAS—$146, Select—$105, No. 1 Common—$76, No. 2 Common—$52, No. 3A Common—$43, and No. 3B Common—$32.

[4] The point at which all free water has been removed from the wood. For red oak this is approximately 24 per cent moisture content, based on oven-dry weight.

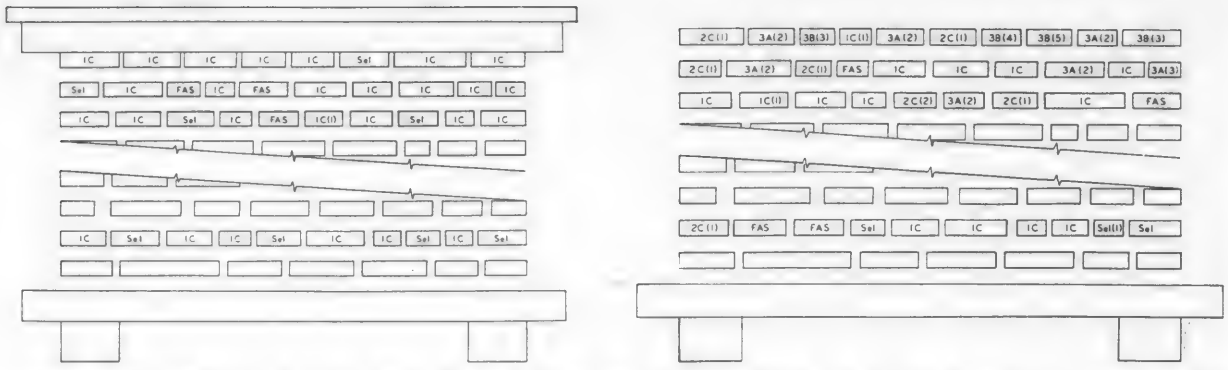

Fig. 2.—After 93 days of air drying during the spring months, little seasoning degrade had occurred in roofed piles (left chart). Conversely, most boards in the top three tiers of non-roofed piles (right chart) had dropped one or more grades. The air-dry grade is shown on the end of each board. The numbers in parentheses show the number of grades lost due to seasoning defects. The occurrence and distribution of degrade in these piles of No. 1 Common and Better lumber are typical of results in all piles during both seasons.

in the non-roofed piles, but because the original moisture content of the sample boards in the roofed piles was less than that in the non-roofed piles, definite conclusions on the effect of pile roofs on over-all rate of drying were not possible. The drying rate of non-roofed lumber was noticeably more sporadic, however, especially during the alternating wet and dry weather in the Spring (Fig. 4). This fluctuation in rate of drying probably contributed to the severe checking of the non-roofed lumber. Neither uniformity nor rate of drying varied by lumber grades.

In addition to providing a steadier rate of drying, the use of pile roofs also increased uniformity of drying within the lumber piles. Boards in the roofed piles differed very little in moisture content, regardless of location. In contrast, the moisture content

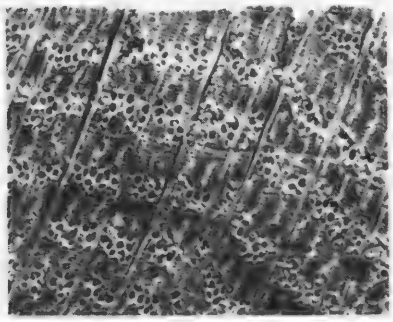

Fig. 3.—Fine surface checks on a red oak board extending from the surface deep into the wood. Such checks remain in the wood to mar the surface of finished products.

Table 1.—COMPARATIVE VALUE LOSSES DUE TO SEASONING DEFECTS IN THE TOP THREE TIERS OF ROOFED AND NON-ROOFED LUMBER PILES[1]

Original grade	Tier[2]	Spring drying period			Summer drying period		
		Value loss in non-roofed piles	Value loss in roofed piles	Advantage of roof	Value loss in non-roofed piles	Value loss in roofed piles	Advantage of roof
		Dollars					
No. 1C and Btr.	1	3.25	0.00	3.25	4.55	0.78	3.77
	2	1.27	.00	1.27	.69	.16	.53
	3	.88	.21	.67	1.17	.00	1.17
Total		----	----	5.19	----	----	5.47
No. 2C	1	1.15	0.00	1.15	1.35	0.16	1.19
	2	.46	.00	.46	.00	.24	—0.24
	3	.26	.00	.26	.09	.08	—0.08
Total		----	----	1.87	----	----	.87
No. 3AC	1	0.80	0.08	0.72	0.80	0.08	0.72
	2	.58	.07	.51	.40	.07	.33
	3	.27	.00	.27	.20	.22	—0.02
Total		----	----	1.50	----	----	1.03

[1] 4/4-inch commercial red oak.
[2] Each tier contained approximately 72 board feet of lumber. Tier 1 was on top.

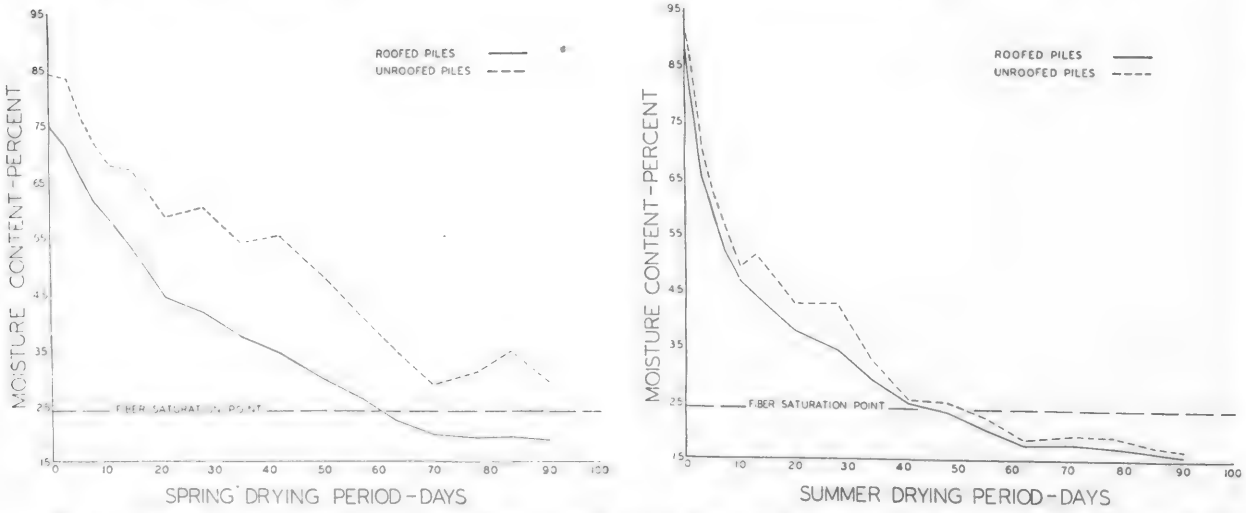

Fig. 4.—During the rainy spring months (left graph), lumber in the roofed piles dried faster and more uniformly than that in non-roofed piles. During the summer months (right graph), lumber in the roofed piles dried only slightly faster than that in the piles without roofs.

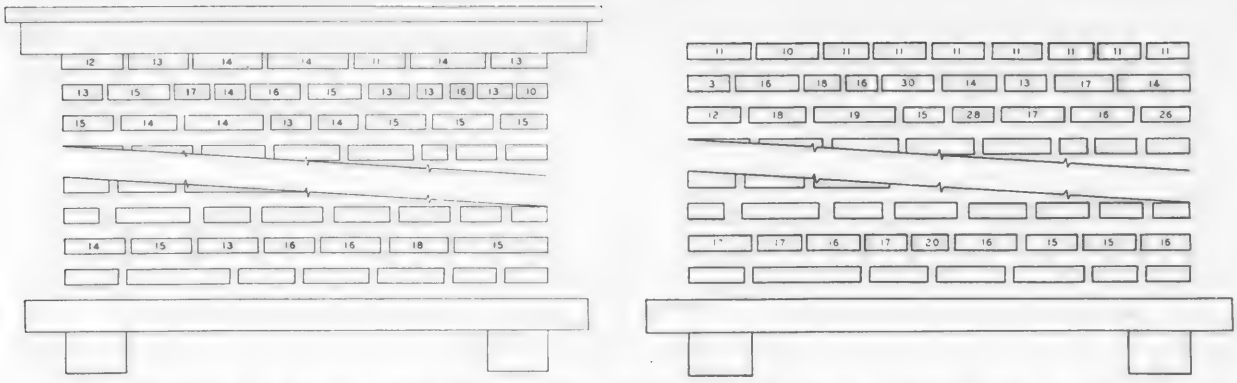

Fig. 5.—Diagrammatic end views of lumber piles with numbers indicating moisture content for individual boards. These figures illustrate the variations that occurred within and between roofed (left chart) and non-roofed piles of 4/4-inch red oak lumber after 105 days of air drying during a dry summer season. The roofed piles, regardless of lumber grade, dried faster and more uniformly during both seasons.

of boards near the center of the piles without roofs was much higher than that of boards near the edges (Fig. 5). This difference was especially noticeable in the spring when, after 95 days of air drying, moisture contents ranged from 15 to 44 per cent within a single pile. The higher moisture content in the center of the non-roofed piles indicates that rate of drying throughout these piles was slower than that for the roofed piles.

Economic Evaluation of Pile Roofs: Most commercial lumber yard operators who roof their lumber for drying expect to spend approximately $25.00 to construct a sturdy, rain-tight pile roof. Those using a forklift can place and remove a roof of this type for about $1.00. If handled with reasonable care, such a roof will usually last about five years.

Considering savings in degrade and drying time,[5] this study shows that a $25.00 lumber pile roof will pay for itself in five uses on No. 1 Common and Better lumber, and in 13 uses on No. 2 Common and No. 3A Common lumber (Fig. 6). If the same roof were used for 20 air-drying periods of 90 days each (approximately 5 years), it could be expected to earn a net profit of $4.50 to $5.00 per use on No. 1 Common and Better lumber, and $.75 to $1.00 per use on No. 2 Common and No. 3A Common. These earnings do not include increased values due to fewer harmful surface checks and to the better appearance of lumber dried under cover.

Summary and Conclusions

This study was designed to investigate the influence of pile roofs on lumber degrade and uniformity of drying during wet and dry seasons in southern Illinois. Within the limitations and scope of this study, the following conclusions were drawn from the results obtained:

1. Little degrade develops in roofed piles during air drying. Conversely, most boards in the top three tiers of non-roofed piles may be expected to drop one or more grades. Severe surface checking—a major seasoning defect—can be greatly reduced by the use of pile roofs.

2. Lumber in roofed piles dries at a more uniform rate, and apparently faster than that in non-roofed piles.

3. A pile roof costing $25.00 can be expected to pay for itself after five 90-day drying periods when used to cover a 6- by 12-foot pile of 4/4-inch No. 1 Common and Better lumber. Assuming such a roof can be used five years, it will earn a net profit of $4.50 to $5.00 per air-drying period in terms of high quality and more uniformly dried lumber.

4. A $25.00 pile roof can be expected to pay for itself after thirteen 90-day periods on a 6- by 12-foot pile of 4/4-inch No. 2 Common and No. 3A Common lumber. If used for five years to cover these grades, it would net $.75 to $1.00 per drying period.

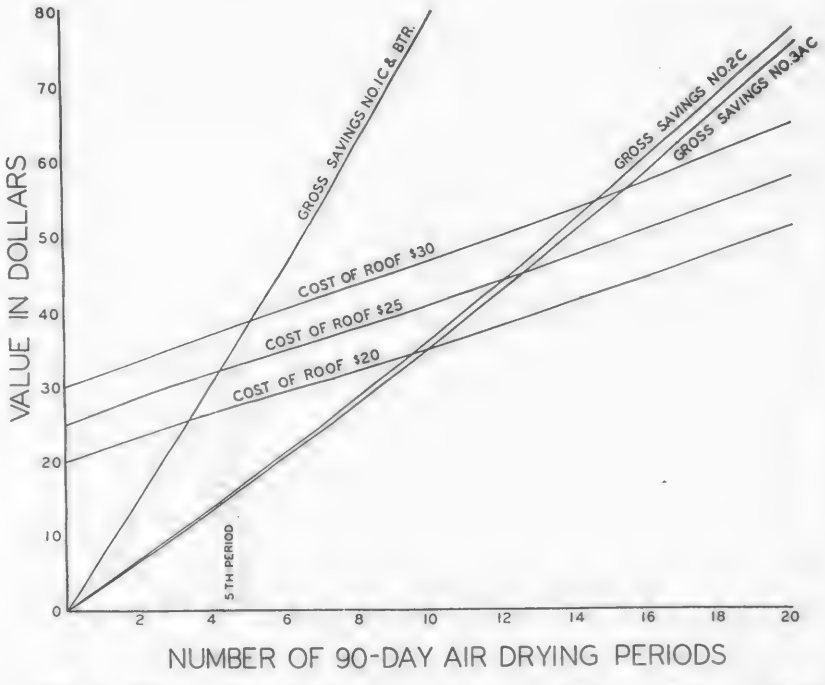

Fig. 6.—This chart shows the number of uses required to pay for constructing and handling pile roofs of three different original costs when used on three grades of lumber. The roof costs are $20, $25, and $30; it costs $1 to place and remove a roof and the life of a roof is assumed to be five years. The interest rate is 6 per cent. Example: A $25 roof used on No. 1 Common and Better lumber will pay for itself during the fifth 90-day drying period. After eight periods, this roof would have cost $38, but would have saved $62 or made a net profit of $24 by reducing seasoning degrade and drying time.

[5] Savings in drying time are based on a kiln cost of $2.00 per thousand board feet per day. Due to differences in moisture content after air drying, lumber from the non-roofed piles would have required an average of one more day in a kiln than lumber air dried in roofed piles.

Abstracts From Current World Literature

Wood Drying

Stevens, W. C. The effect of air speed and flow direction on the drying of a pile of timber. *Timber Technology*, Vol. 66, No. 2225, March 1958, pp. 121–3

It has long been known that the effects of air movement in kiln drying are considerable. An increased air speed tends to promote faster heat transfer and moisture evaporation. However, it must be realized that the wood itself sets a limit to the rate at which surface evaporation may take place without detriment to the material. If this limit can be attained by adjusting the humidity of the air entering, there is no advantage in increasing the velocity of the air when dealing with narrow piles of timber. Normally, commercial piles of timber are not narrow in modern kilns. With a pile 7–8 ft wide and with uni-directional air flow, the drying lag can become quite appreciable and a fast air movement between the runs would reduce this to reasonable limits. Unfortunately, the power requirements of fans increase very rapidly with the speed and increasing the velocity of the air might prove to be costly where it is not possible to install large diameter fans.

A cheaper method is to alternate the direction of air flow. That the alternating air flow leads to more uniform drying and a reduced 'lag', as compared with uni-directional air flow, can be shown by the following. After 60 hours of drying when the inlet samples were at 38% moisture content, the wettest samples were at 73% with uni-directional flow, and only at 57% with alternating flow. [F.D.C. Tech. Bul. V. 7, No. 40]

Chemical Utilization

Bristow, O. J., Sultze, R. F., and Chase, R. R. Soap skimmer studies by analyses of feed and skimmed liquors. *Tappi* 40, no. 10: 809–12 (Oct., 1957).

By using an analytical method for determining the amount of tall oil (soap) in black liquor before and after the skimming operation, the efficiency of the skimming equipment can be determined and factors affecting it evaluated. By this method the most efficient skimmer design, within practical limits, may be chosen. Knowledge of the soap potential of the black liquor as well as skimmer efficiency affords a means of studying fundamental factors affecting actual soap production. It was found that soap-skimmer efficiency varies over a period of months without any change being made in the mode of operation. The fundamental reason for the variation is not known, but it is shown that it affects measured soap production considerably. A description of the analytical method is included as an appendix. [Bul. Pap. Chem. V. 28, No. 4]

Finishes and Finishing

New Methods of Producing Colored Polyester Varnish Coatings. Herbert Niesen. Holz Als Roh- Und Werkstoff V. 16, No. 2.

Various methods for producing colored polyester varnish coatings are described and their applicability in the wood working industry, especially for the manufacture of furniture and for interior decorations, is discussed. Two of the methods described are also suitable for coating large surfaces with polyester varnishes. It appears from the paper that a new kind of surface treatment or coating has been developed that is able to complete the use of plastic boards.

Polyester finishes. Peinture et vernissage du bois, Cahier No. 29, May 1958, pp. 8–10 (in French)
Centre Technique du Bois

In a general review of wood finishes, the research workers of the French Wood Research Centre consider polyester lacquers as most interesting for the furniture industry.

One of their main advantages is stated to be the possibility of applying one coat only and a high solid content (90%) which results in the avoidance of such defects as 'blush' and 'orange peel'. Recommended quantity is 500 g/m².

When used on horizontal surfaces, the authors recommend using a very fluid lacquer (20–22 sec in Ford cup No. 4) to fill in all the pores of the wood. If vertical surfaces are to be sprayed, a thixotropic agent has to be added to the polyester, bringing the viscosity up to 40–50 sec.

It is recommended that they should be dried in a dust-free atmosphere in temperatures not below 18° C (65° F) and not above 70% humidity.

To avoid bubbles in the finish, the lacquers should not be agitated and should be sprayed at maximum opening with low air pressure, 1.5–2 kg/cm² (20–30 lb/sq in) for low viscosity lacquers and 2.5–3 kg/cm² (35–42 lb/sq in) for the high viscosity ones, in all cases from a fair distance of up to 1 ft.

The adhesion will be poor if the moisture content of the timber is over 12%. [F.D.C. Tech. Bul. V. 7, No. 40]

Construction

Adhesives and Sealants in Building. Building Research Institute, Pub. 577, NAS–NRC Publications Office, 2101 Constitution Ave., Washington 25, D. C., 1958, 160 pp, $5.00

A complete picture of progress in the use of adhesives and sealants by the building industry today. Includes 21 papers, fully illustrated, delivered at BRI conference in December 1957. Subject matter includes discussion of the various types of adhesives and sealants; the sealing of joints in the building exterior using traditional materials; the sealing of metal curtain walls; adhesives for the building interior; adhesives for structural components; four papers on the future of adhesives and sealants in building; and reports of panel discussions. [BRI Abstracts, June 1958]

Successful Lu-Re-Co Homes. Lumber Dealers Research Council, Ring Bldg., 18th & M Sts. N.W., Washington 6, D. C., 1957, 15 pp, free

The ten houses shown in this booklet were chosen from a large number of designs which have actually been built with the Lu-Re-Co system. Each house shown was chosen for outstanding qualities which gave it unusual appeal and acceptability. Area of houses ranges from 900 to 1145 sq. ft.; all but one are one story, with the exception being a split-level. [BRI Abstracts, June 1958]

National Design Specification for Stress-Grade Lumber and Its Fastenings. Natl. Lumber Manufacturers Assn., 1319–18th St., N.W., Washington 6, D. C., 1957 Edition, 70 pp, 50¢

Newest edition of this specification, incorporating additional reliable technical data and practical experience. NLMA plans to reissue this specification every three years henceforth, with interim amendments published as supplements to the current edition. In addition to the 9-part specification, there are 12 appendices dealing with such subjects as lateral distribution of a concentrated load, formulas for wood columns with side loads and eccentricity, horizontal shear in checked beams, and others. [BRI Abstracts, June 1958]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Over 70 periodicals are reviewed, plus new books and research reports from industrial, governmental, and academic laboratories and organizations.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

Around the World in Forest Products Research and Development

Future Plans of the Soviet Timber Industry

W. Donald Bowles

Ass't. Prof., Dept. of Economics. The American University, Wash., D. C.

The following is a translation from the Russian newspaper *Izvestia* (News), Nov. 14, 1958. It deals with the proposed Soviet 7-year plan (1959–1965) for the timber industry. The plan contains "control figures" established for development of many phases of Soviet life.

"The control figures provide for a great increase of production in the timber, paper and woodworking industries. Specifically, production of paper and cardboard, particle and fiberboard, prefabricated houses, furniture, plywood, and details will increase. Intensive utilization of wood is planned, as well as processing of roundwood in logging regions so as to greatly reduce transportation of wood in an unprocessed state.

"The total production of wood, not counting that of small loggers, will increase from 322 million cubic meters in 1958 to 372–378 million cubic meters in 1965. Production of industrial wood will increase to 275–280 million cubic meters.

"Production of lumber by planned industry [excluding small local sawmills, apparently] is to increase from 68.6 million cubic meters in 1958 to 92–95 million cubic meters in 1965. In the timber-surplus districts of the North and Siberia, the quantity of sawmilling will increase 1.8 times.

"In the coming years it is planned to increase production of complete prefabricated houses and assemblies of parts for houses with walls made of local construction materials. Furniture production in 1965 is to approach 18 billion rubles, or 2.4 times the level in 1958, and the quality of marketed furniture is to improve.

"The cellulose-paper, wood-chemical and hydrolysis branches of industry must receive major development. A cellulose production of approximately 4.8 million tons in 1965 is planned, or 2.3 times more than in 1958. To provide for the needs of the artificial fibers industry, production of viscose cellulose will be increased to 580 thousand tons in 1965, or 4.5 times.

"Paper production in 1965 is to be approximately 3.5 million tons and cardboard approximately 2.8 million tons, or 1.6 and four times more, respectively, than in 1958. Especially heavy emphasis will be placed on the increase in production of boxing cardboard. Production of newsprint is to increase 1.8 times. Production of paper for the needs of the food industry will increase."

"Capital investment in the timber, paper and woodworking industry will amount to 58–60 billion rubles; that is, it will increase more than two times [in comparison with the previous seven-year period in constant prices. The official ruble-dollar rate of exchange is 4:1, which may overvalue the ruble somewhat.]. Of this sum, approximately 60 per cent will be directed to the development of the cellulose-paper and woodworking industries."

Fire Tests Discussed at FAO Meeting in Madrid

The development of new fire performance tests and realistic building code requirements in relation to wood and wood products were an important goal discussed at the Fourth FAO Conference on Wood Technology at Madrid earlier this year, an article in *Unasylva* reports.

The consensus at the meeting was that codes should be based on actual performance of a specific material, and requirements that a material should have particular inherent properties is not consistent with modern technological methods for protective treatment of materials.

It was reported that methods of treatment employed on a commercial scale can render wood products resistant to fire to the extent that they will not burn except when directly subjected to an external source of heat, and they cease to burn when this source is removed.

Wood technologists at the meeting expressed the need for a test that does not require extensive space and expensive auxiliary equipment. The ultimate aim would be to select a few for international recognition. Most experts thought this was not possible at the present time and that emphasis should be placed on methods directed towards a realistic appraisal of fire hazards.

Exceptional fire resistance of heavy timbers is a well-established fact. Less known are the possibilities to improve the fire resistance of wood structures by design and planning. It was reported that fire losses in wood frame houses in Canada are lower than in other dwellings. Due to appropriate design of frame houses, this has been recognized by a reduction in insurance rates.

Another example reported at the meeting was the case of Netherland door manufacturers. A few years ago these doors had a maximum fire resistance of 10 minutes in a standard test. Today, Dutch manufacturers are able to produce wooden doors with a resistance of 40 to 60 minutes.

Three lines of approach in the development of testing equipment were discernible. They were: tunnel tests; box tests; and radiation panel tests. It was felt that fire testing should lend itself to the evaluation of the behavior of all types of materials during a fire, and that there was no need to develop specific methods for wood and wood-base materials except in cases where fire-protective treatments were involved.

It was recognized that reaction to fire cannot be expressed by only one index. For research purposes it is necessary to report measurements such as ignitability, spread of flame, fire penetration, heat produced by combustion, smoke intensity, and others.

(Unasylva, V. 12, N. 3)

Scanning World Wide Forest Products Publications

Germany

The Microstructure of Novopan-Particle Boards. H. H. Bosshard. *(In German) Holz Als Roh-Und Werkstoff*, V. 16, No. 9.

By the application of a special embedding method the serial microtomy of particle boards can be effected relatively easy. Thus an exact observation of their microstructure becomes possible. The article contains results about the distribution of the porous area and the position of the chips over the cross section of a board.

Practical Utilization of Hardwoods

Kenneth C. Korstian, Rome Kraft Co., Rome, Ga., Presented at the Florida-Georgia-Alabama Section Meeting, Dec. 6, 1957.

The utilization of hardwoods in the South has been increasing over the past 20 years. Hardwood use in 1955 increased 17.5 per cent compared with a gain of 9.8 per cent for pine. Hardwood pulp production in 1956 accounted for 14 per cent of the total roundwood production in the South. In the six counties surrounding Rome, Ga., only 47 cords of hardwood pulpwood were produced in 1955, whereas in 1956 production figures of these six counties totalled 6,572 cords.

During 1957, the Rome Kraft Co. began to accept a limited amount of oak produced from company lands. The use of oak, as well as the soft hardwoods, amounts to about 4 per cent of the mill consumption. Until the mill began to use hardwood, the firm had a policy of hardwood control on the upland areas. The program called for the girdling of cull or unmerchantable hardwoods that were overtopping the young pine seedlings. Such species as post oak, blackjack oak, and hickory, were girdled. Desirable species such as white oak and yellow poplar, were not killed.

In the extreme upper Piedmont Plateau, conditions approaching the coves of the lower Appalachian Mountains are found. These areas are better suited for the growth of high-quality hardwoods such as white oak and yellow poplar, than for pine. Since it would be unwise to attempt a type conversion, these areas are being managed for quality hardwoods.

With the advent of the limited use of oak by the mill, the cull tree removal policy has been modified. Scheduled hardwood pulpwood operations are now part of the timber management program within the truck area. This operation permits the removal of merchantable oak for pulpwood prior to the girdling of the unacceptable species such as hickory and elm. Within the Rome area, many species of oak are now being utilized for pulpwood. Chestnut, scarlet, post, and blackjack oaks from the upland ridges, and willow, water, and southern red oaks from the bottomlands are some of the oak species now being utilized.

A cruise of a 19,000-acre tract in north central Alabama indicated that there were 0.68 cord per acre of soft hardwoods, 1.57 cords per acre of hard hardwoods, and 1.81 cords per acre of cull hardwoods, including hickory. The total merchantable volume of hardwoods amounts to 2.25 cords per acre.

Actual cut on several tracts in the Rome area have yielded about 3.5 cords of merchantable hardwood per acre. Under the earlier program of cull tree removal, this volume would have been girdled and left to decay. In addition to this, between 500 and 600 pine seedlings per acre are being released.

The cull tree removal program on 3,900 acres for the first 11 months of 1957 has required the girdling of an average of 33 square feet of basal area per acre, which has released an average of 930 pine seedlings per acre. In comparison, the removal of the merchantable hardwood for pulpwood has left very little volume in unmerchantable species. The tracts from which the hardwoods have been removed are now in a condition for growth of more desirable trees and species. While the primary concern is pine, a mixture of desirable hardwoods growing as an understory in the pine stands is acceptable.

In conclusion, objectives of the Rome Kraft Co. in the management of hardwoods are to utilize any merchantable hardwoods, to remove the cull hardwoods overtopping pine seedlings, and to improve the quality of hardwood stands by favoring desirable species.

Chips Make Dollars

J. C. Robinson, Simpson Paper Co., Everett, Wash. Presented at a joint meeting of the Inland Empire Section and the Northwest Wood Products Clinic, April 11, 1958 at Spokane, Wash.

At present, over 1/3 of the pulpwood requirements of the West Coast come from so-called wood waste. The only fair way to break down what is in a log is to measure it by weight. Of this weight, 42 per cent is lumber, 26 per cent pulp, 23 per cent sawdust and shavings, and 9 per cent bark. At least 26 per cent of the wood waste could be converted to chips that can be sold to a pulp or paper mill.

Chips generally are sold by the pound or by the unit. When sold by the pound, it is generally by the bone-dry weight. The chips are weighed when wet, and the per cent of moisture is figured on a representative sample. Some firms use weightometers on their conveyor belts, others weigh the whole load and subtract the weight of the container. Some firms buy chips by the unit or 200 cubic feet. One buyer will use the compacted unit, another will use the gravity-fed unit. A compacted unit should weigh bone-dry, about 400 pounds more than a gravity-fed unit, bone-dry.

Simpson Paper Co. buys chips from four different sawmills. One of the mills cuts between 48 and 50 thousand board feet a day. This produces an average of 25 units of chips a day. The cost of producing a unit of chips is about $4.00, which includes the depreciation on the barker, screens, and the chipper. The mill receives $10 a unit for the chips, leaving a profit of $6 per unit or $125 profit per day.

Equipment needed are a barker, chipper, screen, and means for loading the chips. The type of barker to be installed will depend upon the size of the mill and the size of the average log. There is no barker on the market today that can economically bark all logs. The important thing is to install a barker that fits the average size log used in the sawmill. Slabs from rough or oversize logs can be sent to the hog.

The size of the chipper used depends upon the amount that a firm expects to put through it. Although an 8- or 16-knife chipper costs more, it makes more and better chips and saves money in the end. The size of the screens depends on the size of the mill.

Various mills want different size chips. The average size chip is around 5/8 to 7/8 inch in length. All mills are requiring clean and well cut chips, just as the sawmills are demanding better logs.

An important consideration in putting in a chipping plant is whether the species can be segregated. Certain kinds of chips will bring higher prices than others. Some mills will take mixed chips, others only one kind. One way to solve this problem is to sort the logs and cut a certain length of time on one species and then cut another length of time on another.

It is not good business to pick up thinnings and pay the stumpage, trucking, felling, and bucking costs, when good chips are available from the sawmill. The sawmill or plywood mill can make a good profit on chips.

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How to Use the Index

Articles are listed in three ways: by title, by subject and by author. Title and subject listings are combined and appear first. The exact title of each article (omitting only the articles "a", "an", and "the") is indicated by the presence of authors' names in the Title and Subject Index. In addition, each article is listed under one or more subject headings. Categories of subjects, in boldface type, reflect terms in current usage.

The Author Index contains an entry for every author. For articles with a single author, the listing gives author's name, subject, issue number, and page. For articles with two or more authors, the listing for the first author gives all authors' names, subject, issue number, and page; listings for co-authors refer back to the first author. Two or more articles by the same author are listed chronologically.

If the exact title or an author's name is known, an article can be located quickly. If neither the title nor author's name is known, there are many clues by which an article can be found. For example, an article on high-temperature drying of birch may be found under both Seasoning and Birch.

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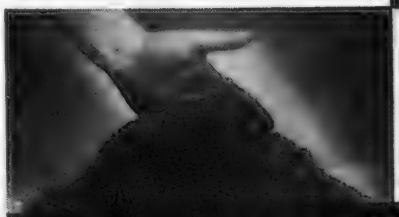

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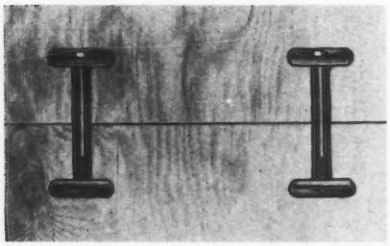
New Products—Literature

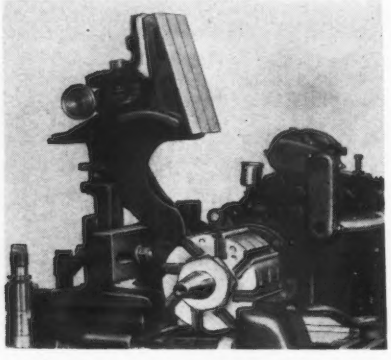


New Fastener for U or L Counters

A "Lok–Joint" Fastener is now being produced by Van Dyke Industries. An open-end wrench is used for installation, the manufacturer reports, and can be made up either wet or dry. The "Lok–Joint" was designed to work well in close quarters such as U or L shaped counters. More information is available from Van Dyke Industries, 3625 Cahuenga Blvd., Los Angeles 28, Calif.

Improved Moulder Announced

Features of the revised 137 MT Moulder made by the S. A. Woods Machine Co. have been announced recently. Adjustments and stock handling can be performed in less time, the firm reports.



The machine was designed for accessibility to the top head and the ability to remove it in less than a minute. The top head chip breaker has adjustable sectional shoes and is equipped with counter-balanced springs. The distance between the operator and the rear stock guide is less than 15 inches. More information is available from the S. A. Wood Machince Co., 27 Damrell St., Boston 27, Mass.

Five New Sintered Carbide Tools Announced

Five new abrasive products, a hand sander, a wood rasp or file, a contour rasp or file, an abrasive saw, and an abrasive saw and sanding disc, which incorporate the use of crushed sintered tungensten carbide, are now being produced by Functional Products, Inc.

These products, called "Tunco," are produced by copper bonding crushed tungsten carbide particles to steel in a hydrogen atmosphere brazing furnace under high temperatures. More information is available from Functional Products, Inc., 1460 East River Road South, Aurora, Ill.

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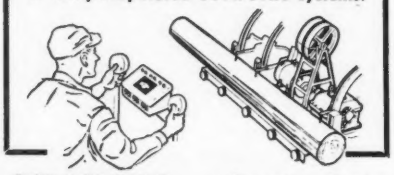

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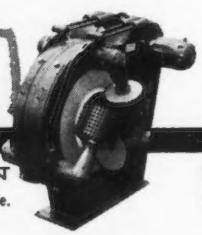

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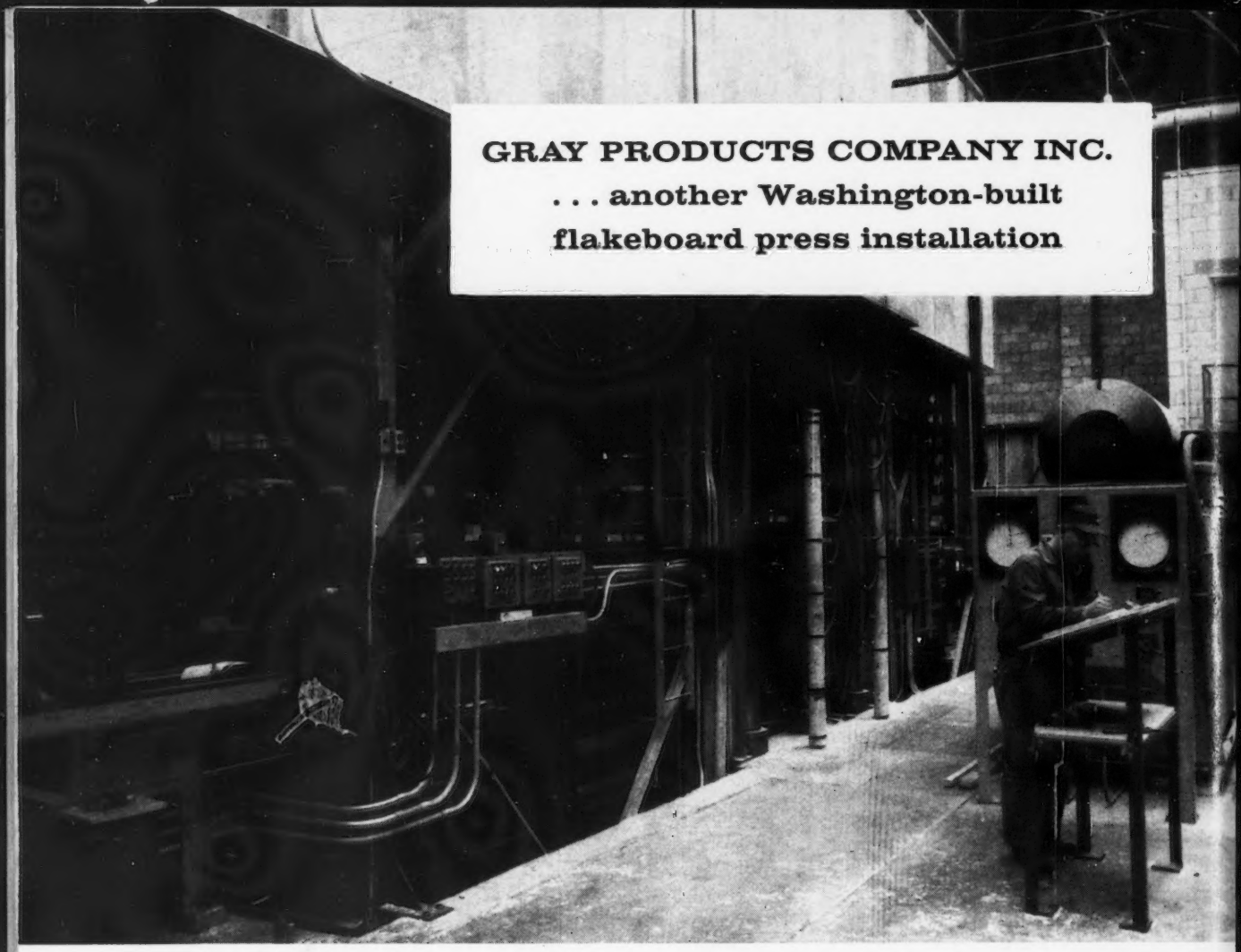

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